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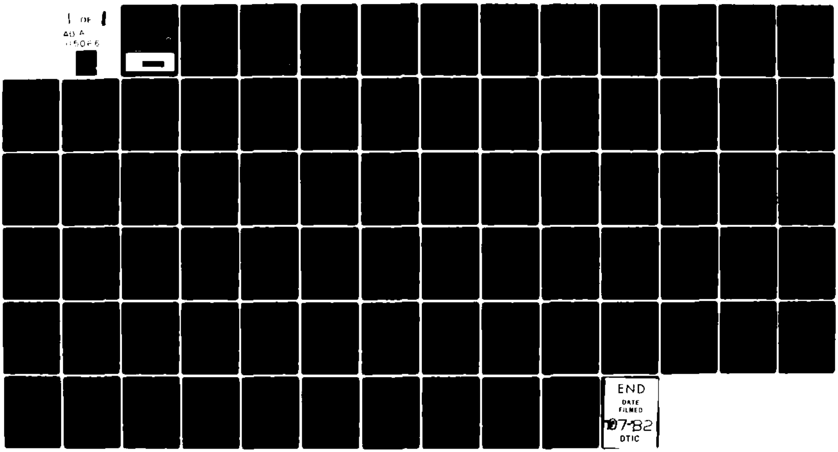

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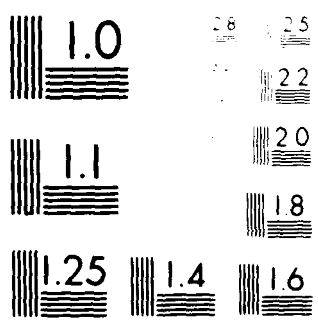
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SYSTEM ENGINEERING ANALYSIS OF FORCED DRAFT BLOWERS INSTALLED ON AFS-1, AOE-1, AND AOR-1 CLASS SHIPS

May 1982

Prepared for
PLANNING AND ENGINEERING FOR REPAIRS AND ALTERATIONS
COMBAT SUPPORT SHIPS
HUNTERS POINT NAVAL SHIPYARD
SAN FRANCISCO, CALIFORNIA
under Contract N00189-81-D-0126-FJ06

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This report documents the historical maintenance experience for the forces draft blowers (FDBS), ship's work authorization boundary (SWAB) 251-1, installed on AFS-1, AOE-1, and AOR-1 Class ships. It presents an analysis of the existing maintenance policy and recommends specific maintenance actions and maintenance policy modifications to improve system materiel condition.

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by

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FOREWORD

This report documents the historical maintenance experience for the forced draft blowers (FDBs), ship's work authorization boundary (SWAB) 251-1, installed on AFS-1, AOE-1, and AOR-1 Class ships. It presents an analysis of the existing maintenance policy and recommends specific maintenance actions and maintenance policy modifications to improve system materiel condition.

SUMMARY

The goal of an engineered operating cycle (EOC) program is to effect an early improvement in the materiel condition of ships at an acceptable cost, while maintaining or increasing their operational availability during an extended operating cycle. In support of this goal, system engineering analyses (SEAs) are being conducted for various ship classes on selected mission-critical systems and subsystems that have historically exhibited relatively high maintenance burdens. This report documents the SEA for the forced draft blowers (FDBs) installed on AFS-1, AOE-1, and AOR-1 Class ships.

The SEA is an analysis of the impact of historical preventive and corrective maintenance requirements that affect operational performance and maintenance programs of a ship system and the significance of these requirements to an EOC program. The report documents a recommended system maintenance policy and specific maintenance actions best suited to meeting EOC goals.

The report on this SEA was originally submitted in July 1981 as ARINC Research Publication 2614-11-4-2494. That publication is superseded by this submission, which presents comments resulting from the Navy's review of the original report. Comments were received from NAVSSES 023C; where necessary, ARINC Research incorporated revisions or additions to address those comments.

The SEA included an examination of all available maintenance data sources. The documented maintenance experience of each separate system configuration was reviewed and data analyzed from the maintenance data system (MDS), casualty reports (CASREPs), past ship alteration and repair packages (SARPs), post-overhaul analysis reports (POARs), and Destroyer Engineered Operating Cycle (DDEOC) Program system maintenance analyses (SMAs) previously conducted for functionally similar systems and equipments installed on DDEOC Program ships. Initial findings for these sources were correlated with current planned maintenance system (PMS) requirements, existing and planned system alterations, and system technical manual data. Discussions were held with representative shipboard operating personnel and appropriate technical personnel in NAVSEA to the extent necessary to validate identified maintenance requirements

and undocumented maintenance requirements and to determine the status of current and planned actions affecting each system design. Appropriate review comments of the in-service engineering agent (ISEA), NAVSSES 023C, have been incorporated into this SEA. All findings were evaluated, and appropriate conclusions were developed.

On the basis of these conclusions, a recommended system maintenance policy was defined, and recommendations were made to implement the policy by periodically performing specific types of corrective maintenance. Also included, for specific systems and equipments subjected to detailed analysis, were recommendations for improving system preventive maintenance; integrated logistics support; reliability, maintainability, and availability; and depot- and intermediate maintenance activity (IMA)-level capabilities. Implementing these combined recommendations will minimize the adverse impact of corrective maintenance requirements on the extended operating cycle.

The major findings and conclusions of the SEA for AFS-1, AOE-1, and AOR-1 Class FDBs are summarized as follows:

- FDB governors and steam admission valves for the AFS-1, AOE-1, and AOR-1 Classes are the only equipments identified in this analysis that clearly benefitted from depot-level overhauls. Class B overhauls of the other FDB equipments did not improve equipment reliability or availability; therefore, such action is not recommended. These equipments can be repaired, as needed, by ship's force and IMAs.
- A significant amount of corrective maintenance is a function of how clean the ship's force maintains the lube oil subsystem. Many significant failures, associated with contaminated lube oil, occurred randomly throughout the data period examined.
- The FDB lube oil system modifications to be installed as shipalts to the AFS-1, AOE-1, and AOR-1 Class ships are expected to reduce the corrective maintenance burden and improve FDB reliability and maintainability when installed.
- With limited IMA assistance, ships' forces are capable of accomplishing most repairs to the combat support ship FDBs, with the following exceptions:
  - -- The Woodward governors installed aboard AOR-1 through -6. These cannot be properly maintained or repaired by ship's force, IMAs, or shipyards.
  - -- Catastrophic failures of FDBs. These are usually caused by operating accidents and are not the result of equipment wear-out.
- AOR-1 Class ships have experienced a FDB governor failure rate significantly higher than that of the AFS-1 or AOE-1 Classes. Therefore, extension of the governor overhaul interval beyond five years is not considered prudent.

- AOE-1 Class FDB governors need to be overhauled only once every six years; more frequent overhauls are unnecessary due to a phased maintenance repair strategy, a relatively low failure rate, and sufficient equipment redundancy (four boilers, eight FDBs). Six years, however, should not be construed to be the maximum possible governor repair interval. It is anticipated that the interval could be extended beyond six years, but a maximum interval could not be determined because no AOE-1 Class ships have operated longer than five years.
- AFS-1 Class FDB governors need to be overhauled only once every five years. More frequent overhauls are unnecessary due to a phased maintenance repair strategy and a relatively low failure rate. Five years, however, should not be construed to be the maximum possible governor repair interval. It is anticipated that the interval could be extended beyond five years; however, such action would offer significant risk due to the lack of equipment redundancy aboard AFS-1 Class ships (three boilers, three FDBs).

CONTENTS

CONTENTS (continued)

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

System engineering analyses (SEAs) are being conducted on selected systems and subsystems of designated ships of the Mobile Logistic Support Force (MLSF) in support of an engineered operating cycle (EOC) program. The SEA is an analysis of the impact of historical preventive and corrective maintenance requirements that affect the operational performance and maintenance programs of a ship system. It serves as a vehicle for assessing the significance of these maintenance requirements to an EOC program. The objective of this SEA is to define and document a maintenance program for the forced draft blowers (FDBs) installed aboard AFS-1, AOE-1, and AOR-1 Class ships that will prevent or minimize the need for unscheduled maintenance, while improving material condition and maintaining or increasing system availability throughout an engineered operating cycle.

This revised report incorporates appropriate review comments of cognizant NAVSSES technical codes.

1.2 SCOPE

The analysis documented herein is specifically applicable to the forced draft blowers, ship's work authorization boundary (SWAB) 251-1, installed on AFS-1, AOE-1, and AOR-1 Class ships. It considers only the systems and equipments installed and documentation effective as of 30 September 1980. This system was selected for analysis by PERA (CSS) on the basis of its mission criticality and historical maintenance burden.

The analysis used all available documented data sources from which system maintenance requirements could be identified and studied. These included the maintenance data system (MDS), casualty reports (CASREPs), planned maintenance system (PMS) requirements, past ship alteration and repair packages (SARPs), post-overhaul analysis reports (POARs), system alteration information, system technical manuals, and Destroyer Engineered Operating Cycle (DDEOC) system maintenance analyses (SMAs) previously

conducted for functionally similar systems and equipments installed on DDEOC Program ships. Sources of undocumented data used in this analysis included discussions with ships' operating personnel and cognizant Navy technical personnel.

1.3 REPORT FORMAT

The following chapters describe the analysis approach (Chapter Two), present the significant system maintenance experience and essential maintenance requirements (Chapter Three), and summarize the conclusions and recommendations derived from the analysis (Chapter Four). Appendix A defines the system boundaries used in conducting this analysis, and Appendix B lists the specific components that constitute the FDBs as installed on individual ships of the ship classes under study. Appendix C presents the major design differences among the different AFS-1, AOE-1, and AOR-1 Class FDB designs. Appendix D presents a summary of the FDB CASREPs by FDB design and CASREP cause (Table D-1) and a CASREP parts summary (Table D-2). Appendix E presents a summary of the use of significant parts, reported through MDS. A summary and status of FDB shipalts is presented in Appendix F. Appendix G lists the sources of information used in this analysis.

CHAPTER TWO

APPROACH

2.1 OVERVIEW

This chapter describes the approach followed in performing the SEA for the forced draft blowers, SWAB 251-1, installed on AFS-1, AOE-1, and AOR-1 Class ships. The system was selected for analysis by PERA (CSS) on the basis of its mission criticality and historical maintenance burden. Data from sources mentioned in Section 1.2 were used to identify, define, and analyze maintenance requirements that will significantly affect the system's operational availability and materiel condition. A recommended maintenance strategy and implementation procedures were formulated on the basis of the analysis results. The major steps of the analysis were as follows:

- Task 1: Compile data and prepare maintenance history profile
- Task 2: Analyze problems and causes
- Task 3: Analyze solutions to problems
- Task 4: Document SEA results

The following sections briefly describe each of the major tasks.

2.2 TASK 1: COMPILE DATA AND PREPARE MAINTENANCE HISTORY PROFILE

During this task, the configuration, boundaries, and functions of the system were defined; maintenance, engineering, and operating data were collected; and the maintenance history profile was prepared, describing the corrective maintenance historically performed. These items provided basic reference data for the remaining SEA tasks. A major result of this task was a functional description of the system.

2.2.1 Collect Data

The analysis began with the collection of data on the historical maintenance requirements of each system. The resulting data file consisted of four key elements: an MDS data bank, a CASREP narrative summary, a

current equipment configuration summary, and a summary of historical maintenance requirements. A library was also assembled of appropriate technical manuals, PMS requirements, SARPs, POARs, and copies of previously completed analyses of functionally similar equipments installed on DDEOC Program ships.

The MDS data bank was compiled by examining all MDS data reported for hulls AFS-1, -3, -4, -5, -6, and -7; AOE-1 through -4; and AOR-1 through -7 (17 ships total) from 1 January 1971 through 30 June 1980. Data on AFS-2 were not included in the analysis; they were inadvertently omitted from the data base due to an error in the unit identification code used to initially request the data. No effort was made to reorder the data, because the limited potential for improvement of the MDS data bank did not warrant the time and cost involved in obtaining and integrating AFS-2 data. This omission does not affect the analysis results. CASREP information was obtained by reviewing the CASREPs reported on each ship's system during the data period. CASREPs resulting from parts cannibalization of equipments by other ships were not considered.

2.2.2 Define System Configuration

Configuration information was obtained by reviewing available common configuration class lists (CCCLs), the type commander's coordinated shipboard allowance lists (COSALs), shipalt records, and MDS data. Telephone calls to specific ships and cognizant technical personnel, as necessary, confirmed system configuration.

2.2.3 Prepare Maintenance History Profile

The maintenance history profile was prepared from analyses of MDS and CASREP data and review of applicable PMS documentation, past SARPs, and POARs. The maintenance history profile describes the types of corrective and restorative maintenance historically performed on the system, the level of maintenance typically required to perform the work, an estimate of the man-hours required, and the approximate intervals at which these maintenance actions can be anticipated.

2.3 TASK 2: ANALYZE PROBLEMS AND CAUSES

In this task the data summarized on the maintenance history profile form were analyzed, together with the available engineering data, to identify maintenance, support, and design problems and their associated causes. The problems and their causes were confirmed and data related to additional problems were uncovered through discussion with ships' forces and Navy technical personnel when possible.

2.3.1 Analyze Data to Define Problems

Recurring maintenance requirements affecting the availability and materiel condition of the equipments constituting the system were identified by screening the maintenance historv profiles developed in Task 1. Screening of the maintenance history profiles had two major objectives:

- Identification of recurring failure modes or problems requiring IMA, depot, or other off-ship assistance for correction that are associated with all engineering designs of the functionally similar equipments installed on AFS-1, AOE-1, and AOR-1 Class ships
- Identification of recurring failure modes or problems that are either unique to or primarily associated with a particular equipment engineering design installed on a limited number of hulls

Once the problems were identified, the previously completed DDEOC Program SMAs for functionally similar equipments were reviewed to determine whether the same or similar problems had been previously identified on other ship classes. If such was the case, the need for additional detailed analysis was minimized.

2.3.2 Define Causes

Although it is presented as a separate subtask, the definition of problem causes was a continuing process that occurred concurrently with the definition of the problems. Concurrent effort was required for the following reasons:

- Problem causes were sometimes stated in the historical maintenance data.
- Causes or possible causes of problems were identified during discussions with Navy technical personnel or ships' forces.
- Problem causes had previously been identified by analysis of identical or functionally similar systems installed on other ship classes.

In general, the causes were grouped into three categories -- maintenance strategy, design, and support.

2.3.3 Summarize Problems and Causes

The problems identified and the causes defined in Task 2 were summarized and carried forward to Task 3 for development of specific solutions. The summary descriptions included the following data:

- A statement of the problem and the most probable cause
- A summary of the pertinent maintenance history and engineering data, including man-hours, number of actions, and level of repair
- Other information affecting the problem, such as redesign work in process, applicable alterations, or the effects of availabilities

2.4 TASK 3: ANALYZE SOLUTIONS TO PROBLEMS

In this task, the problems identified in Task 2 were analyzed so that a recommendation could be made regarding a maintenance strategy, a support strategy, or design changes for the associated equipments, or regarding equipment that should be replaced.

2.4.1 Conduct Analyses to Develop Candidate Solutions

The development of candidate solutions consisted of three steps:

- Step 1: Analyze existing solutions. The analysis of existing design solutions, whether applicable to AFS-1, AOE-1, and AOR-1 Classes or to other previously analyzed ship classes
- Step 2: Analyze potential maintenance strategies. The analysis of maintenance strategies that could possibly apply or that have been effectively applied under similar circumstances to other ship classes
- Step 3: Analyze potential solutions to integrated logistics support (ILS) problems. The analysis of possible improvements to the ILS that might be implemented under similar circumstances on other ship classes

2.4.1.1 Analyze Existing Solutions

The analysis of existing design solutions that may be applicable to the three ship classes under study had two basic objectives. The first was to determine whether the problem was known to the Navy technical community and whether or not a solution had been proposed or defined. To find out, currently authorized shipalts affecting the system or equipment under study were reviewed and, if needed, interviews were conducted with Navy technical personnel.

The second objective was to determine if the specific problem exists in other ship classes and, if so, whether a solution had been defined and if it was applicable to the problem associated with the ship classes under study. To meet this objective, previously completed analyses of functionally similar equipments installed on other ship classes were reviewed, and the various problems found were evaluated to determine if they were similar. If the problems were determined to be similar to those identified in this analysis, the previously developed solutions were assessed for applicability to the particular equipments installed on AFS-1, AOE-1, and AOR-1 Class ships. If found to be applicable, they were adopted and documented as recommendations in this report without further detailed analysis.

2.4.1.2 Analyze Potential Maintenance Strategies

Previously developed maintenance strategies for functionally similar equipments installed on other ship classes were reviewed for their applicability to equipment installations on AFS-1, AOE-1, and AOR-1 Class ships. If shown to be applicable by this analysis, they were adopted and recommended for implementation on these classes of ships.

In cases where previously identified maintenance strategies did not apply to AFS-1, AOE-1, or AOR-1 Class systems or equipments, an analysis was conducted of maintenance strategies that could possibly apply, using reliability-centered maintenance (RCM) logic. This approach used the information developed during previous tasks to answer a series of simple yes-no questions, which led to specific decisions concerning the suitability of scheduling maintenance tasks. The following three types of maintenance tasks could result from the decision process:

- On-condition task - Inspect equipment operation to detect either experienced or impending failures
- Scheduled rework task - Rework an item before an established maximum age or operating interval is exceeded
- Scheduled discard task - Discard an item before an established maximum age or operating interval is exceeded

The results of this process led to the development of the maintenance strategies recommended for the systems and equipments under study for which previously developed maintenance strategies were inadequate.

2.4.1.3 Analyze Potential Solutions to ILS Problems

Analysis of possible improvements to the ILS of the systems and equipments under study was limited to only those systems or equipments having maintenance history profiles that indicated the presence of such problems. Such problems are typically identified during review of MDS or CASREP data. Excessive downtime awaiting parts and the lack of authorized on-board spares as reported in CASREPs indicated the existence of ILS problems. MDS narratives were also used to identify ILS problems, since the deferral codes frequently indicated that a particular maintenance action was deferred for lack of spare parts, technical documentation, or training or experience on the equipment. In those instances where ILS problems were identified, previously completed analyses of functionally similar systems or equipments were reviewed to determine if similar ILS problems had been identified. If they had, and if satisfactory solutions had been defined and recommended, those solutions were adopted and documented as recommendations in this report without further detailed analysis. If not, further analysis was conducted to define an appropriate solution.

Each ILS problem was assessed in terms of its significance and the feasibility of successfully implementing a cost-effective solution. Only those solutions judged to be essential and cost-effective were recommended.

2.4.2 Select Effective Solutions

An effective solution was selected by the analyst on the basis of its merit or essentiality with respect to its projected cost and risk. All candidate solutions, whether resulting from this analysis or from previously conducted analyses of functionally similar equipments, that were

judged to materially improve personnel safety or primary mission reliability were evaluated, and the best solutions, in terms of value versus cost, were selected and recommended for implementation. Candidate solutions to problems not significantly related to personnel safety or mission reliability were assessed on the basis of projected cost and feasibility. If these candidate solutions were not clearly feasible, or if their value, in terms of reduced maintenance burden or improved equipment reliability, was not significant, they were not recommended for implementation.

2.5 TASK 4: DOCUMENT SEA RESULTS

The approach used for this task was to present the analysis results in a concise, logical format that included an introduction to the SEA objectives, a summary of the technical approach used, a presentation of the analysis results, and a section listing the specific conclusions and recommendations resulting from the analysis. Appendixes were included as necessary to show pertinent data affecting the system, including a table defining the equipment configurations by allowance parts list (APL) number for each AFS-1, AOE-1, and AOR-1 Class hull included in the analysis.

CHAPTER THREE

RESULTS

3.1 SYSTEM BOUNDARIES AND DESCRIPTION

The forced draft blowers discussed in this report are composed of those equipments included within SWAB group 251-1. All the major equipments (listed in Appendix A) were examined to identify maintenance requirements. The major components examined and discussed in this report are listed by APL number in Appendix B. Minor components such as drain valves, filters, and light indicators were not examined in detail because past experience has shown that these components are not maintenance- or mission-critical and are usually repaired or replaced as needed by ship's force and thus require no periodic repairs.

Each of the FDBs installed on the AFS-1, AOE-1, and AOR-1 Class ships, hereafter referred to as the combat support ships, consists of a fan-type blower mounted on a common shaft with a steam-driven turbine. Each self-contained unit includes an integral lubricating system and oil sump, a speed-limiting governor system, and a low-oil-pressure trip mechanism. Output of the blowers is controlled by the governor system, which regulates the flow of steam to the turbine.

The FDB units are integral parts of the combustion system. They are used for supplying combustion air to the main steam generators (boilers). Therefore, the loss of a FDB directly affects the operation of the associated boiler. (Each FDB supplies combustion air to a particular boiler. FDBs cannot be cross connected and used with different boilers.) The loss or partial degradation of a boiler affects the mobility of a ship, a primary mission area for the combat support ships.

Appendix C lists FDB differences by ship class; it shows that each AFS-1 Class ship has one FDB installed for each of three boilers. The appendix also shows that each ship of the AOE-1 and AOR-1 Classes has two FDBs installed for each of four and three boilers, respectively. Ships' forces have confirmed that two boilers (with all associated FDBs) or three boilers, each with one FDB (for AOE-1 and AOR-1 Class ships only) will support all normal ship evolutions for the combat support ships. (Normal ship evolutions include under-way replenishments.) Therefore, the loss of one FDB has a negligible effect on the ship's mission capabilities. However, an AFS-1 Class ship would have no backup boiler, an AOR-1 Class

ship would have a reduced backup capability (one boiler with one of two FDBs), and no combat support ship could operate at full power. The loss of two FDBs would seriously impair the operability of an AFS-1 Class ship. Ships of the AOE-1 and AOR-1 Classes could still conduct all normal operations with two FDBs inoperative; in fact, the AOE-1 Class ships could lose as many as five FDBs and still have sufficient resources to operate. The mission criticality of the FDBs varies across the different combat support ship classes with the FDBs being most critical aboard AFS-1 Class ships and least critical aboard AOE-1 Class ships.

The major design differences among the different combat support ship FDB installations are identified in Appendix C. Differences in manufacturers, blower outputs, turbine speeds, and turbine operating steam temperatures exist within ship classes and across ship classes. The individual design differences are not discussed in this report unless they are identified as being responsible for a significant difference among the maintenance histories of the various FDB installations. For the purposes of this report, "significantly different" is defined as a maintenance parameter difference of more than 100 percent. One hundred percent was selected because past experience has shown that the maintenance reporting practices among ships may differ a great deal, even though the actual maintenance experiences were similar. It is anticipated that a factor of 100 percent should compensate for most of these reporting inconsistencies.

3.2 MAINTENANCE REQUIREMENT IDENTIFICATION

The maintenance data were initially screened to identify the possible existence of significant maintenance-related problems unique to a particular engineering design, as discussed in Section 2.3. Maintenance burden summaries of the various FDB installations are presented in Table 3-1. The burdens shown represent the combined maintenance burdens of all the FDB components for each unique installation (different blower APL); they are listed by ship class and primary APL. Table 3-1 shows that the reported annual maintenance burdens for the different FDB designs examined were between 5.4 and 96.9 man-hours per component operating year. These initial results indicate that two designs (those installed aboard AFS-1 and AOE-3 and -4), have significantly more maintenance man-hours reported against them than the other designs examined. It is also apparent that two FDB designs (those installed aboard AOE-1 and AOR-7) have significantly fewer man-hours reported against them than the remaining FDB designs. The annual equipment parts costs reported for three FDB designs (AFS-3 through -7, AOE-3 and -4, and AOR-1 through -6) were approximately 2.8 to 11.6 times greater than that of the next most significant design. These gross differences of two maintenance parameters indicate that the maintenance experiences of some FDBs examined may be significantly different.

The available MDS and CASREP data for each FDB component (listed in Appendix B) were examined to identify the reasons for the maintenance man-hour expenditure and parts cost inconsistencies and to identify any maintenance tasks that would periodically require the assistance of an IMA,

Table 3-1. MAINTENANCE BURDEN SUMMARY DATA FOR FORCED DRAFT BLOWERS

APL	Nomenclature	Applicable Ships	Components per Ship	Total Component Population	Total Ship Operating Time (Ship-Years)	Ships Reported	CNs	Ship's Force Man-Hours	IMA Man-Hours	Total Man-Hours	Parts Cost (Dollars)	Average Man-Hours per Component per Operating Year*	Average Parts Cost per Component per Operating Year*
057960013	Fan, Steam, Turbine Driven 32000 CFM	AFS-1	3	3	8.8	1	53	1,913	644	2,557	1,795	96.9	67.9
057960020	Fan, Steam, Turbine Driven 34400 CFM	AFS-3,-4, -5,-6,-7	3	15	43.8	5	155	1,849	959	2,808	24,999	21.4	190.2
057960012	Fan, Steam, Turbine Driven 28400 CFM	AOE-1	8	8	8.6	1		71	1	372	3,188	5.4	46.3
057990011	Fan, Steam, Turbine Driven 42000 CFM	AOE-2	8	8	8.5	1	41	975	927	1,902	3,380	27.9	49.7
057800180	Fan, Steam, Turbine Driven 41000 CFM	AOE-3,-4	8	16	16.3	2	319	7,837	887	8,724	102,611	66.9	786.9
057990018	Fan, Steam, Turbine Driven 22000 CFM	AOR-1,-2, -3,-4,-5,-6	6	36	46.3	6	403	4,325	2,804	7,129	92,699	25.7	333.7
057960034	Fan, Steam, Turbine Driven 22000 CFM	AOR-7	6	6	4.6	1	12	63	147	210	1,305	7.6	47.3

*Average Man-Hours (Parts Cost) per Component Operating Year = $\frac{\text{Total Man-Hours (Parts Cost)}}{\text{Total Ship Operating Years}} \div \frac{\text{Total Component Population}}{\text{Number of Applicable Ships}}$

depot, or maintenance activity other than ship's force. The data were first categorized by functional subsystem or component. Ship's force and IMA man-hour expenditures for each subsystem or component are summarized by FDB design in Tables 3-2 and 3-3. The man-hours that could not be assigned to a single subsystem or component because individual maintenance transactions often reported repairs to several different components were grouped into the appropriate "Other" or "Unknown" categories. Nonspecific repairs and repairs judged to be "one-time" or "non-maintenance-related," such as "FDBs overhauled by SRF," "manufacture instruction plates," or "install electric lube oil pump" were also grouped into these categories.

The results indicate that there are significant differences in the subsystem and component ship's force and IMA man-hour expenditures for the various FDB designs. AOE-3 and -4 reported expending approximately 69 percent of their ship's force man-hours repairing the FDB lube oil subsystem. These repairs totaled 5,408 ship's force man-hours, almost ten times the number of ship's force man-hours reported for lube oil subsystem repairs by any other FDB design installation. AFS-1 and AOE-3 and -4 reported significantly more ship's force man-hours for turbine repairs, specifically bearing and thrust shoe repairs, than the other FDB designs examined. AOR-1 through -6 reported approximately five times the average number of ship's force man-hours per component operating year for governor repairs. AFS-1 reported expending more than seven times the average number of ship's force man-hours per component operating year for valve maintenance.

Examination of the FDB IMA man-hour summary, Table 3-3, shows that the expenditure of IMA man-hours was fairly consistent across the different FDB installations. Significant exceptions are annual component IMA man-hours reported by AFS-1 for repair of lube oil subsystem pumps and motors, turbine rotor shafts, and control valve assemblies, as well as the governor repairs reported by AOR-1 through -6. Table 3-3 also shows that AOE-1 and AOR-7 reported very few IMA man-hours for almost all FDB components.

Generally, it appears that ships' forces perform the majority of the required maintenance for the FDB units and that IMA assistance is most often required for maintenance or repairs to the lube oil subsystem and various unit valves.

The available maintenance data were examined further for the following purposes:

- Identification of the failure modes associated with the reported maintenance man-hours
- Determination of the cause of each failure mode
- Determination of an appropriate maintenance level for the correction of each failure mode
- Determination of the failure mode periodicities
- Determination of the effect of each failure mode on equipment availability and its associated effect on mission-critical areas

Subsystem or Component	Subsystem or Component Ship's Force Man-Hours								Average Ship's Force Man-Hours per Subsystem or Component per Operating Year							
	AFS-1, AFS-2*	AFS-3, AFS-7	AOE-1	AOE-2	AOE-3, AOE-4	AOR-1, AOR-6	AOR-7	All Hulls	AFS-1, AFS-2*	AFS-3, AFS-7	AOE-1	AOE-2	AOE-3, AOE-4	AOR-1, AOR-6	AOR-7	All Hulls
1. Lube Oil Subsystem																
a) Coolers	2	353	8	0	157	9	20	549	.08	2.7	.1	0	1.2	.03	.7	.7
b) Pumps & Motors	99	170	23	16	1,878	1	0	2,187	3.8	1.3	.3	.2	14.4	0	0	3.0
c) Other	17	23	80	2	3,373	440	9	3,944	.6	.2	1.2	.03	25.9	1.6	.3	5.3
Subtotal	118	546	111	18	5,408	450	29	6,680	4.5	4.2	1.6	.3	41.5	1.6	1.0	9.0
2. Turbine																
a) Bearings & Shoes	877	102	10	2	562	152	0	1,705	33.2	[illegible]	.1	.03	4.3	.5	0	2.3
b) Blades	0	55	0	0	352	0	0	407	0	.4	0	0	2.7	0	0	.5
c) Rotor Shaft	158	0	0	0	0	20	0	178	6.0	0	0	0	0	.1	0	.2
d) Casing	0	97	101	0	0	0	0	198	0	.7	1.5	0	0	0	0	.3
e) Other	0	10	0	0	0	0	0	10	0	.1	0	0	0	0	0	.01
Subtotal	1,035	264	111	2	914	172	0	2,498	39.2	2.0	1.6	.03	7.0	.6	0	3.4
3. Valves																
a) Steam Admission	2	84	1	28	56	252	13	436	.08	.6	.01	.4	.4	.9	.5	.6
b) Exhaust, Relief	288	114	9	2	124	90	0	627	10.9	.9	.1	.03	1.0	[illegible]	0	.8
c) Root Steam	259	26	0	0	8	279	0	572	9.8	.2	0	0	.1	1.0	0	.8
d) Drain (& pipes)	0	253	0	6	51	195	0	505	0	1.9	0	.1	.4	.7	0	.7
e) Control Valve Assembly	149	0	0	0	17	0	0	166	5.6	0	0	0	.1	0	0	.2
Subtotal	698	477	10	36	256	816	13	2,306	26.4	3.6	.1	.5	2.0	2.9	.5	3.1
4. Governor																
a) Low Lub. Oil Trip	0	16	0	24	62	10	0	112	0	.1	0	.4	.5	.04	0	.2
b) Other	14	70	9	25	105	977	0	1,200	.5	.5	.1	.4	.8	3.5	0	1.6
Subtotal	14	86	9	49	167	987	0	1,312	.5	.6	.1	.7	1.3	3.6	0	1.8
5. Labyrinth Seals	0	128	1	20	502	457	3	1,111	0	1.0	.01	.3	3.8	1.6	.1	1.5
6. Lagging	1	22	22	6	72	74	0	197	.04	.2	.3	.1	.6	.3	0	.3
7. Tachometers, Gages, Thermometers	3	10	19	7	192	33	5	269	.1	.1	.3	.1	1.5	.1	.2	.4
8. Other or Unknown	44	316	88	837	326	1,336	13	2,960	1.7	2.4	1.3	12.3	2.5	4.8	.5	4.0
Totals	1,913	1,849	371	975	7,837	4,325	63	17,333	72.5	14.1	5.4	14.3	60.1	15.6	2.3	23.4

Table 3-2. FDB SHIP'S FORCE MAN-HOUR SUMMARY

*No MDS data are recorded for AFS-2, as discussed in Section 2.2.1.

Table 3-3. FDB IMA MAN-HOUR SUMMARY

Subsystem or Component	Subsystem or Component Ship's Force Man-Hours								Average Ship's Force Man-Hours per Subsystem or Component per Operating Year							
	AFS-1, AFS-2*	AFS-3, AFS-7	AOE-1	AOE-2	AOE-3, AOE-4	AOR-1, AOR-6	AOR-7	All Hulls	AFS-1, AFS-2*	AFS-3, AFS-7	AOE-1	AOE-2	AOE-3, AOE-4	AOR-1, AOR-6	AOR-7	All Hulls
1. Lube Oil Subsystem																
a) Coolers	0	476	0	0	19	0	147	642	0	3.6	0	0	.1	0	5.3	.9
b) Pumps & Motors	230	49	0	0	233	63	0	575	8.7	.4	0	0	1.8	.2	0	.8
c) Other	0	4	0	50	20	18	0	92	0	0	0	.7	.2	.1	0	.1
Subtotal	230	529	0	50	272	81	147	1,309	8.7	4.0	0	.7	2.1	.3	5.3	1.8
2. Turbine																
a) Bearings & Shoes	0	16	0	200	0	2	0	218	0	.1	0	2.9	0	0	0	.3
b) Blades	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c) Rotor Shaft	124	0	0	0	0	0	0	124	4.7	0	0	0	0	0	0	.2
d) Casing	0	15	0	0	0	0	0	15	0	.1	0	0	0	0	0	0
e) Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	124	31	0	200	0	2	0	357	4.7	.2	0	2.9	0	0	0	.5
3. Valves																
a) Steam Admission	0	30	0	26	0	178	0	234	0	.2	0	.4	0	.6	0	.3
b) Exhaust, Relief	54	15	0	50	147	226	0	492	2.0	.1	0	.7	1.1	.8	0	.7
c) Root Steam	0	0	0	0	0	349	0	349	0	0	0	0	0	1.2	0	.5
d) Drain (& pipes)	45	114	0	0	0	1	0	160	1.7	.9	0	0	0	0	0	.2
e) Control Valve Assembly	138	0	0	0	0	0	0	138	5.2	0	0	0	0	0	0	.2
Subtotal	237	159	0	76	147	754	0	1,373	9.0	1.2	0	1.1	1.1	2.7	0	1.8
4. Governor																
a) Low Lube Oil Trip	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b) Other	0	60	0	0	0	723	0	783	0	.4	0	0	0	2.6	0	1.1
Subtotal	0	60	0	0	0	723	0	783	0	.4	0	0	0	2.6	0	1.1
5. Labyrinth Seals	0	32	0	0	244	319	0	595	0	.2	0	0	1.9	1.4	0	.8
6. Lagging	0	0	0	0	0	30	0	30	0	0	0	0	0	.1	0	0
7. Tachometers, Gages, Thermometers	12	58	0	0	31	61	0	162	.4	.4	0	0	.2	.2	0	0
8. Other or Unknown	41	90	1	601	193	834	0	1,760	1.6	.7	0	8.8	1.5	3.0	0	2.4
Totals	644	959	1	927	887	2,864	147	6,369	24.4	7.3	0	13.6	6.8	10.1	5.3	8.6

*No MDS data are recorded for AFS-2, as discussed in Section 2.2.1.

- Development of alternatives that would increase equipment availability and reduce corrective maintenance when warranted

Examination of the data did not identify any design-related or maintenance-related reasons why AOE-1 and AOR-7 reported relatively few FDB maintenance man-hours, but indicated that maintenance actions reported were similar in type to those of other ships of the same classes though reported with fewer man-hours and at greater intervals than other ships. Examination of MDS data for other propulsion systems also revealed very few maintenance man-hours reported by these ships relative to other combat support ships. Therefore, it has been assumed that these two ships are, in fact, experiencing FDB maintenance comparable to that of other ships of the same classes, but that the maintenance is not being documented in the MDS. The remaining sections of this chapter treat AOE-1 as if its maintenance history were similar to that of AOE-2, and treat AOR-7 as if its maintenance history were similar to AOR-1 through -6. The actual maintenance data reported by AOE-1 and AOR-7 were considered, on a component basis, when it was greater than (more maintenance man-hours or more maintenance actions per time period) that reported by comparable ships.

The following sections present the significant failure modes identified for the FDB units and the associated corrective maintenance and maintenance recommendations. The data are discussed by functional component or subsystem for ease of presentation, and are presented by ship class unless the maintenance experiences of the different FDB design installations within any ship class are significantly different. A failure is defined as any malfunction or condition that, if left uncorrected, will immediately or eventually degrade the FDB availability and reduce mission capabilities. The significant failure modes are presented in a series of tables included in the following sections. Each table lists those failure modes, reported through MDS or CASREP data, that occurred more than once in the data periods examined for the appropriate selected component. All one-time failures and failures whose causes could not be determined from the available data were grouped into the "Other" or "Other or Unknown" categories. The tables also show which hulls reported each failure mode category, as well as the total number of equipment maintenance actions for each ship class as reported in MDS. An equipment maintenance action is defined as each occurrence per equipment of a corrective action directly responding to the occurrence of a particular significant failure mode. The number of CASREPs per ship class (not necessarily the same hulls reporting in MDS) and the number of times outside assistance was reported through MDS are also listed for each significant failure mode. The tables include MDS maintenance actions that have not been reported as completed. Therefore, the number of actual outside assistance maintenance actions is probably greater than the totals indicated in the tables. However, the tables do indicate which failure modes often require outside assistance to correct and which failure modes infrequently require outside assistance.

The subsystems and component groups associated with the significant FDB unit failure modes are discussed in the following subsections:

Subsystem or Component Group	Subsection
Lube Oil Subsystem	3.2.1
Turbines	3.2.2
Valves	3.2.3
Governor Subsystem	3.2.4

Other FDB unit repairs, checks, tests, and considerations are presented in Section 3.2.5, and FDB maintenance strategies are discussed in Section 3.3. All recommendations are summarized by type and component in Chapter Four.

Appendix D presents a summary of the FDB CASREPs by FDB design and CASREP cause and a CASREP parts summary. Appendix E presents a summary of the significant parts usage reported through MDS. A summary and status of FDB shipalts is presented in Appendix F.

3.2.1 Lube Oil Subsystem

3.2.1.1 Discussion

The MDS data and ships' forces indicate that lube oil system contamination and related corrosion is the primary cause of FDB downtime and, therefore, corrective maintenance man-hours. Lube oil contamination causes rusting of the coolers, journal and thrust bearings, and lube oil sump; clogging of the lube oil coolers and filters; rupture of the lube oil coolers; high lube oil operating temperatures; premature wearout of journal and thrust bearings; and governor malfunctions. The number of CASREPs and the number of corrective maintenance man-hours generated solely because of lube oil subsystem contamination could not be determined, but all sources of information indicate the lube oil subsystem contamination is the most significant FDB maintenance problem. Table 3-4 lists the significant repetitive failure modes reported for the FDB lube oil subsystems of the combat support ships. The information presented in this table indicates that a majority of the ships examined have experienced lube oil subsystem failures due primarily to lube oil system contamination.

New Developments

AOE-3 and -4 reported an excessive number of maintenance man-hours due to lube oil subsystem contamination early in the data base examined (see Tables 3-2 and 3-3). Alteration equivalent-to-repair (AER) AOE-15 was developed and later superseded by AER-AOE-39 to improve the FDB lube oil cooling system reliability, ensure constant lube oil pressure, and thus ensure a clean system to increase FDB reliability. This AER modified the gear spray nozzles to prevent clogging, modified the lube oil piping to increase lube oil cooling, installed Cuno-type filters in place of the air maze lube oil filters with differential pressure gauges, modified the

Table 3-4. SIGNIFICANT FAILURE MODES: LUBE OIL SUBSYSTEM

Failure Mode	AFS Class				AOE Class				AOR Class			
	Ships Reported (Hull No.)	Equipment Maintenance Actions	Outside Assistance Maintenance Actions*	CASREPs Reported	Ships Reported (Hull No.)	Equipment Maintenance Actions	Outside Assistance Maintenance Actions*	CASREPs Reported	Ships Reported (Hull No.)	Equipment Maintenance Actions	Outside Assistance Maintenance Actions*	CASREPs Reported
1. Lube Oil Subsystem												
a) Corroded, clogged	-	-	-	-	-3,-4	30	-	1	-	-	-	1
b) Contaminated with water	-	-	-	-	-3	5	-	-	-	-	-	-
c) High lube oil temperatures	-	-	-	-	-3	3	-	-	-	-	-	-
d) Other/unknown	-	-	-	-	-	-	-	1	-	-	-	-
2. Coolers												
a) Tubes ruptured	-1,-3,-4, -5,-6	16	I/9,D/1	-	-3,-4	[illegible]	I/[illegible]	-	-1,-7	9	I/9	-
b) Corroded, scaled	-3,-6	7	I/3	-	-1,-2, -3,-4	17	I/4,D/6	-	-	-	-	-
3. Attached Lube Oil Pump												
a) Drive shaft, gears worn	-	-	-	-	-3,-4	24	I/10	1	-2,-5	2	I/1	1
b) Low output pressure	-4	1	-	-	-3	1	-	-	-	-	-	-
c) Inoperable	-4	1	-	-	-	-	-	1		-	-	2
4. Aux. Lube Oil Pump Motor												
a) Windings burnt, open	-1	8	I/5	-	-	-	-	-	-	-	-	-

*D = Depot, I = IMA, TR = Technical Representative.

lube oil coolers, installed an Amot-type thermostatic lube oil temperature control valve, and increased the lube oil sump capacity among other changes. AER-AOE-39 was installed on AOE-3 during the regular overhaul (ROH) of 1974-5 and on AOE-4 during the ROH of 1976-7. Prior to the installation of this AER, the average man-hours per component operating year (COY) for the FDB lube oil system, including the maintenance reported against the lube oil pumps, motors, coolers, sumps and piping, the governor, and the thrust and journal bearings calculated to be approximately 95.6 for AOE-3 and 48.8 for AOE-4. Subsequent to the installation of AER-AOE-39, the average man-hours per component operating year for the same equipments and parts are calculated to be approximately 27.6 and 28.8, respectively. The reported maintenance burden for these equipments and parts has decreased significantly. (This group of equipments and parts were selected for this comparison because they are the equipments and parts constantly affected by the lube oil cleanliness and pressure.)

The Navy technical community has since taken further steps to ensure cleanliness of the FDB lube oil system for the combat support ships through the steam propulsion plant improvement program for 600 psi ships, PMS 301. Shipalts have been and are still being developed to improve and standardize the FDBs of the combat support ships. The status of applicable combat support ship shipalts is shown in Appendix F.

Shipalts AFS-1-393K, AOE-1-446K, and AOR-1-421K, all entitled FDB Lube Oil System Mods, are intended to provide a standardized FDB lube oil system with improved capability for removal of water and contaminants and oil temperature control, and to provide an auxiliary lube oil pump automatic startup capability. These shipalts will accomplish the following:

- Install a centrifugal separator capable of removing water and solid contaminants from the lube oil, and a lube oil supply motor and pump on the side of the lube oil sump

- Mount the auxiliary lube oil pump and motor on the FDB to include a red pump running light on the controller and auxiliary control console (ACC), and a pressure-activated switch in the oil supply line to the turbine bearings. (This new configuration is designed to activate the auxiliary lube oil pump at low lube oil pressures, when the attached lube oil pump pressure is ineffective, and to deactivate the auxiliary lube oil pump at higher lube oil pressures, when the attached lube oil pump pressure is sufficient. Most AFS-1 Class ships have no auxiliary lube oil pumps and motors at present, whereas the AOE-1 and AOR-1 Class ships have auxiliary lube oil pumps and motors.)

- Remove the existing duplex oil filters and install the new Cuno simplex filter with drip pan, and a differential pressure indicator that activates an alarm when the filter needs cleaning

- Replace the existing four-way cooler bypass valve with an Amot thermostatically operated valve (An Amot valve may have previously been installed under Shipalt AOR-1-469, AFS-1-416, or AER-AOE-39.)

- Flush, hydrostatically test, and operationally test to ensure that bearing lube oil temperatures are maintained at 120 $\pm$ 5 degrees F

It is anticipated that these lube oil system modifications will significantly reduce lube oil system contamination, clogging, and corroding, increase the operational life of turbine bearings, coolers, and governors, and reduce the present ship's force and IMA maintenance burden for these components and the lube oil system. It is anticipated that the incidence of all the present lube oil system failure modes shown in Table 3-4 will be significantly reduced or totally eliminated when the shipalts discussed above are installed. These shipalts are programmed for accomplishment on the combat support ships during Fiscal 1982 through Fiscal 1987.

SARP Review

Available combat support ship SARPs show that the FDB lube oil subsystems, including coolers, pumps, motors, controllers, sumps, and piping, usually received Class B overhauls (14 of 17 reviewed) during shipyard availabilities. However, the FDB lube oil subsystem maintenance history as reported through MDS and CASREPs indicates that the maintenance experience after overhauls was no better after a Class B overhaul than after Class C repairs. Two ships (AFS-5 and AOE-4) reported a total of six lube oil cooler failures, tubes ruptured or corroded, less than one year after receiving a Class B overhaul. Two ships (AOR-1 and AOR-5) have reported no significant lube oil subsystem failures over a total of three ship operating years since receiving Class C repairs. AFS-1 has reported auxiliary lube oil pump motor failures on four occasions since receiving Class C repairs. These lube oil pump motors were replaced with different motors and the new motors were relocated to provide a cooler ambient temperature. This particular failure mode was not reported again in the data base examined and is expected to occur infrequently during future operating cycles. Excluding this design-related failure mode, AFS-1 has not reported a significant lube oil subsystem failure in 2.7 ship operating years since receiving Class C repairs. It is therefore concluded that present FDB lube oil subsystems gain no apparent benefit from Class B overhauls, and such action is not recommended. Class C repairs as needed and a thorough cleaning of the lube oil subsystem will adequately support this subsystem through operational periods.

PMS Evaluation

PMS maintenance index pages (MIPs) for the combat support ships' turbine-driven FDBs, hereafter referred to as the applicable FDB MIPs, were examined to evaluate lube oil subsystem preventive maintenance practice differences and identify possible PMS inadequacies. Table 3-5 presents a summary of the PMS MIP differences for the FDB lube oil subsystems. All applicable FDB MIPs require daily sampling and inspection of the lube oil when operating, weekly draining of the lube oil filter, monthly backflushing, and semiannual cleaning of the lube oil cooler watersides. The applicable FDB MIP requirements vary for the cleaning and inspecting of lube oil filters. AFS Class ships have no requirement to inspect the lube

Table 3-5. MAINTENANCE INDEX PAGE DIFFERENCES: [illegible] SUBSYSTEM

Maintenance Index Page Number	Applicable Ships	Periodicity Code				
		Clean and Inspect Lube Oil Filters	Clean Lube Oil Sump		Inspect and Measure [illegible]	[illegible]
			Purify Lube Oil	Renew Lube Oil		
F-002/037-28	AOE-1	Q-3 R-5Q	Q-5R		No Requirement	C-6
F-002/067-76	AFS-1,-2	No Requirement		Q-5R	No Requirement	C-6
F-002/073-72	AOE-2	W-2	M-3		C-1	C-6
F-002/085-87	AFS-3,-4 -5,-6,-7	No Requirement	Q-5R		No Requirement	C-6
F-002/115-40	AOR-1,-2 -3,-4,-5,-6	R-7Q	Q-11R		No Requirement	60M-4
F-002/126-29	AOE-3,-4	R-3Q	M-2R		A-2	C-5
F-002/136-85	AOR-7	W-2		Q-2	No Requirement	C-4

oil filters; the other combat support ships have weekly or quarterly requirements to accomplish this task. In view of the need to provide maintenance consistency, the lube oil contamination problem reported by all ships regardless of FDB design, and the FDB problems that have a potential for reduction (premature wearing of lubricated bearings, governor malfunctions, lube oil cooler clogging), weekly cleaning and inspection of the lube oil filters is recommended for all FDB designs. The appropriate FDB MIPs should be updated to include this change. (This task should be reevaluated after accomplishment of the applicable FDB lube oil system modification shipalts.)

All applicable FDB MIPs list a cyclic or 60-month requirement to deliver the lube oil coolers to a repair facility to be chemically cleaned, hydrostatically tested, and repaired as necessary. MDS data indicate that this task is being accomplished more often than once each cycle due to premature tube ruptures and clogging. Ships' forces and available SARPs indicate that all lube oil coolers are usually chemically cleaned, tested, and repaired during regular overhauls, as required by the PMS. If it is assumed that FDBs experience little or no operation during regular overhauls, then lube oil cooler cleaning, testing, and repairs were accomplished approximately once per ship every 0.81 ship operating year (SOY) for AFS-1 Class ships (65 total occurrences), every 0.44 SOY by AOE-1 Class ships (75 total occurrences) and every 0.99 SOY by AOR-1 Class ships (51 total occurrences). Intracycle repairs were most often reported in groups rather than one cooler being repaired at a time; that is, AFS-1 Class ships usually repaired all 3 coolers at one time, AOE-1 Class ships usually repaired 4 coolers (half of the total installed), and AOR-1 Class ships usually repaired 3 coolers at once (half of the total installed). Therefore, since these repairs can be expected to continue in the near future, it is recommended that AFS-1 Class ships accomplish this task every 2.5 years (3 of 3 coolers), AOE-1 Class ships accomplish this task every 2 years (4 of 8 coolers), and AOR-1 Class ships accomplish this task every 3 years (3 of 6 coolers). MDS data indicate that this task may be accomplished at the IMA or depot repair level and that it will require approximately 30 IMA man-hours per cooler. (These tasks should be reevaluated after the accomplishment of the applicable FDB lube oil system modification shipalts.)

It is also recommended that the applicable FDB MIPs be updated to include this maintenance strategy and that all cyclic tasks be assigned periodicities (in years) to avoid confusion during phased maintenance and other EOC programs.

The applicable FDB MIPs require monthly or quarterly purifying or changing of the lube oil and cleaning of the lube oil sump. The available maintenance data indicate that the different task periodicities (monthly or quarterly) and the different task requirements (purifying or changing lube oil) have had no apparent effect on FDB corrective maintenance, i.e., one maintenance practice resulted in no fewer significant casualties than any other. Therefore, changes to this PMS task group are not warranted.

Ships' forces report a problem gaining access to lube oil sumps on AOE-3 and -4. Technicians are not able to adequately clean the lube oil

sump because they cannot reach all inside areas. Hence, some sludge and possibly rust remains after purifying the lube oil and cleaning the sump. Those areas that cannot be reached should be exactly identified and appropriate action taken to correct this problem.

The applicable FDB MIPs further indicated that inspection and measurement of the lube oil pump drive gear assembly backlash is scheduled annually, cyclicly, or not at all. Table 3-4 shows that AOE-3 and -4 are the only ships that reported attached lube oil pump drive gear failures more than once during the MDS data period. Therefore, MIPs for the remaining combat support ships need not add or change this requirement on the basis of an unacceptable number of lube oil pump drive gear failures. However, it is recommended that this task be developed and added to MIPs F-002/037-28, F-002/067-76, F-002/085-87, F-002/115-40, and F-002/136-85 to identify possible drive gear repairs during regular overhauls.

MIP F-002/126-29 requires AOE-3 and -4 to inspect and measure the attached lube oil pump drive gear assemblies annually. Assuming that this task was normally accomplished as scheduled, the excessive number of drive gear failures indicates that either the gears are not properly aligned or are not properly lubricated. Review of the applicable JCNs indicated the following:

- The MDS cause reported was always "Normal Wear and Tear."
- The casualties were usually discovered during inspection or during PMS (23 of 24 incidents).
- Three narratives indicated that the gear assembly lube oil spray nozzles were clogged (solid contaminants in the lube oil).
- Four narratives indicated that the drive gears were rust covered (water in the lube oil).
- Only one narrative indicated that gears were misaligned.
- This failure mode is a continuing problem -- the reported incidents of this failure occurred throughout the data period examined.

It is anticipated that this failure mode will continue until the FDB lube oil system modifications discussed earlier are accomplished. Therefore, it is recommended that ships' forces continue to inspect the lube oil pump drive gears annually and effect repairs as needed until Shipalt AOE-1-446K is accomplished. After that happens, PMS task F-002/126-29 #A-2 should be reevaluated to determine its need.

The PMS requirements discussed above should protect the lube oil subsystems to the greatest degree possible with the present equipment installations and identify subsystem problems. The design changes discussed earlier will provide greater system cleanliness when accomplished. These changes should be made at the earliest opportunity.

Water Contamination

Water contamination of the lube oil subsystem will be detected during the daily operating sample-and-inspect PMS checks and corrected by purifying or changing the oil. There are several sources of this water in the lube oil: (1) deterioration of the turbine labyrinth seals, (2) leaking exhaust/relief valves, and (3) condensation in the lube oil sump which results when the blower and gland exhaust fans are secured. Items 1 and 2 are discussed in Sections 3.2.2 and 3.2.3, respectively. Prior FDB analyses* have determined that the practice of keeping the gland exhaust system lined up and the gland exhaust fan running at all times for FDBs and other turbine-driven equipment has three potential benefits:

- It can remove the moisture resulting from the condensation of gland sealing steam in the turbine casing that may be entering the lube oil sump.
- It can help prevent rust formation in the turbine casing by removing moisture.
- It can lessen moisture collection in the gland exhaust fan motor windings and bearings, thus decreasing the frequency of bearing replacements and motor rewindings.

However, discussions with Naval Ship Systems Engineering Station (NAVSSES) 023C personnel indicate that running the gland exhaust fan and keeping the gland exhaust system lined up to idle machinery will reduce the performance of the gland exhaust fan and reduce the vacuum at the seals of operating machinery. Thus, this practice is not recommended.

NAVSSES personnel also indicated that gland exhaust systems are sometimes too small to adequately support the applicable main propulsion equipments. This problem has led to the development of shipalts, which increase the gland exhaust system capacity by installing larger gland exhausters and larger condensers for some destroyer class ships. It could not be determined whether the gland exhaust systems installed on the combat support ships are adequate. It is recommended that the need for gland exhaust system upgrading be examined and appropriate action be taken if upgrading is determined to be necessary.

3.2.1.2 Conclusions

Review of the significant lube oil subsystem failure modes documented in Table 3-4 indicates that the subsystem requires corrective maintenance primarily due to contamination; this contamination is a function of how clean the ship's force keeps the subsystem, not of the usual equipment wear-related failures. Hence, it is not possible to estimate when

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*SMA 37-104-251, DDG-37 Class Combustion Air System, ARINC Research Publication 1652-03-13-1739, April 1978.
SMA 1626-200, CG-16 and CG-26 Class 1200 PSI Propulsion Plant, SWAB Group 200, ARINC Research Publication 1671-04-3-2119, November 1979.

particular system failures might occur. Review of the significant failure modes indicated that most failures did occur randomly.

The present FDB lube oil subsystems gain no apparent benefit from Class B overhauls, and such action is not recommended, as discussed in the SARP review subsection of Section 3.2.1.1. Depot assistance is required infrequently. IMA assistance is usually needed to perform those corrective repairs that ships' forces do not have the time and manpower to accomplish. The MDS data and ships' forces indicate that, with the exception of cleaning, hydrostatically testing, and repairing the lube oil coolers, ships' forces are capable of correcting most lube oil subsystem failures without outside assistance, assuming that a normal complement of trained personnel are on board and the operational schedule permits such action.

The applicable FDB MIPs, as revised by this analysis, should ensure the maximum cleanliness of the lube oil subsystem that the present configurations will allow. The FDB lube oil subsystem modifications (shipalts) are expected to increase subsystem cleanliness and therefore increase FDB reliability and availability. These shipalts should be accomplished as soon as possible.

The applicable FDB MIPs and the ship's current ship's maintenance projects (CSMPs) should adequately identify those Class C repairs to be accomplished during SRAs and depot availabilities. Ships' forces, with IMA assistance, are able to effect all expected repairs to the FDB lube oil subsystem during the intracycle. These repairs should be performed as they are needed.

3.2.1.3 Recommendations

The recommendations resulting from this review of the lube oil subsystem maintenance data are as follows:

- Repair FDB lube oil subsystems as found to be necessary by PMS MIPs, as revised by this analysis, and the ship's CSMP. Repairs are to be accomplished as required by ships' forces, with IMA assistance.
- Make the following additions or changes to incorporate a weekly requirement to clean and inspect oil filters for the listed MIPs:

  F-002/037-28, change Q-3 to W-( ) and R-5Q to R-( )W
  F-002/067-76, add W( ) requirement
  F-002/085-87, add W( ) requirement
  F-002/115/40, change R-7Q to R-( )W
  F-002/126-29, change R-3Q to R-( )W

  These tasks should be reevaluated after the accomplishment of the applicable FDB lube oil system modification shipalts.

- Chemically clean, hydrostatically test, and repair the FDB lube oil coolers at the frequencies shown:

  AFS-1 Class -- 2.5 years (3 of 3 installed)
  AOE-1 Class -- 2 years (4 of 8 installed)
  AOR-1 Class -- 3 years (3 of 6 installed)

  These tasks should be reevaluated after the accomplishment of the applicable FDB lube oil system modification shipalts.

- Make the following changes to the listed PMS MIPS: (Task -- chemically clean, hydrostatically test, and repair FDB lube oil coolers.)

  F-002/037-28, change C-6 to 24M-( ) (4 of 8 installed)
  F-002/067-76, change C-6 to 30M-( ) (3 of 3 installed)
  F-002/078-72, change C-6 to 24M-( ) (4 of 8 installed)
  F-002/085-87, change C-6 to 30M-( ) (3 of 3 installed)
  F-002/115-40, change 60M-4 to 36M-( ) (3 of 6 installed)
  F-002/126-29, change C-5 to 24M-( ) (4 of 8 installed)
  F-002/136-85, change C-4 to 36(M) (3 of 6 installed)

  These tasks should be reevaluated after the accomplishment of the applicable FDB lube oil system modification shipalts.

- Assign periodicities (in years) to all cyclic C-( ) requirements of the applicable FDB MIPs.

- Identify those areas of the AOE-3 and -4 lube oil sump that cannot be reached for cleaning and initiate appropriate action to correct this problem.

- Develop and add a requirement to inspect and measure lube oil pump drive gear assembly backlash each ROH to the following MIPs:

  F-002/037-28, F-002/067-76, F-002/085-87, F-002/115-40, and F-002/136-85

- Accomplish the FDB lube oil modification shipalts at the earliest opportunity.

- Examine the need for upgraded gland exhaust systems on the combat support ships and take appropriate action if upgrading is determined to be necessary.

3.2.2 Turbines

3.2.2.1 Discussion

Table 3-6 presents the significant failure modes reported for the combat support ship FDB turbines, including the journal and thrust bearing assemblies and the exhaust relief valves.

Turbine Rotor and Casing

AOE-4 has experienced an unusual number of turbine blade repairs and replacements. Review of the applicable MDS data and CASREPs, and discussions with ships' forces have not identified any wear-related or maintenance-related causes for these repairs. AOE-4 reported as casualties all eight

Table 3-6. SIGNIFICANT FAILURE MODES: TURBINE

Failure Mode	AFS Class				AOE Class				AOR Class			
	Ships Reported (Hull No.)	Equipment Maintenance Actions	Outside Assistance Maintenance Actions*	CASREPs Reported	Ships Reported (Hull No.)	Equipment Maintenance Actions	Outside Assistance Maintenance Actions*	CASREPs Reported	Ships Reported (Hull No.)	Equipment Maintenance Actions	Outside Assistance Maintenance Actions*	CASREPs Reported
1. *Turbine*												
a) Rotating blades bent, weak	-7	1	I/1	-	-4	12	D/1, TR/8	8	-	-	-	-
b) Shaft scored, out of alignment	-4	1	-	-	-	-	-	-	-4	1	-	-
c) Casing ruptured, warped	-6	1	-	-	-1	1	D/1	1	-	-	-	-
d) Labyrinth packing failed	-1,-3-4, -5.	6	I/2	-	-1,-2,-3, -4	12	D/2, I/2	4	-1,-2,-4	5	I/3	1
e) General repairs, overhaul	-1,-5	4	-	-	-1,-2,-3, -4	11	D/2, I/4	-	-1,-4	3	TR/1	-
f) *Unknown*	-	-	-	-	-	-	-	4	-	-	-	-
2. Bearings												
a) Thrust shoes worn	-1	2	-	-	-3,-4	7	-	1	-2	1	-	-
b) Thrust bearings worn, failed	-1,-5	4	TR/1	1	-1,-4	6	-	-	-2,-5	3	-	-
c) Journal bearings worn	-1,-4	8	-	-	-3,-4	4	-	1	-1,-2,-6	5	-	-
3. Exhaust/Relief Valves												
a) Leaks	-1,-3	4	-	-	-2	4	I/4	-	-4	2	I/1	-
b) Inoperable	-	-	-	-	-1,-3,-4	4	I/2	-	-	-	-	-
c) Other/Unknown	-1	3	I/3	-	-1	4	D/4	-	-4	2	I/2	-

*D = Depot, I = IMA, TR = Technical Representative.

FDBs due to "weak" turbine blades approximately two months before the end of a regular overhaul period. All eight FDBs had received a Class B overhaul during that availability. Turbine blades have been replaced on four other occasions since that overhaul. The total CASREP downtime reported for these repairs was 23,800 hours, all due to maintenance. The ship then reported 232 ship's force man-hours in four equipment maintenance actions for the turbine blade replacements since overhaul. These four equipment maintenance actions reported a parts cost for turbine blades of $22,199, plus another $2,366 for packing, seals, and bearings. These parts costs total almost 24 percent of the total parts cost reported for the AOE-3 and -4 FDBs during the data period examined.

As evidenced by the turbine blade failures reported by the remaining combat support ships (see Table 3-6), turbine blades do not fail frequently. Turbine blades are designed to last for the life of the FDB. Turbine blade replacement, when necessary, may be caused by improper installation, defective blades, foreign matter in the turbines (such as a shot of water), or improper startup or shutdown practices. This type of casualty can be corrected by ship's force with limited IMA assistance, and should be corrected as necessary.

Rotor shafts that are scored or out of alignment and ruptured or warped turbine casings are also failure modes that (1) are reported infrequently, (2) are usually caused by a lack of maintenance or improper operating practices, and (3) can be repaired by an IMA or depot with ship's force assistance. Since there is no apparent indication of improper operating procedures from reported failures, discussions with ships' forces, or review of available FDB technical manuals, these failure modes are expected to occur infrequently in the future and can best be remedied as they occur.

Labyrinth Seals

Labyrinth packing wears out and requires replacing. Most of the combat support ships have reported replacing their labyrinth seals at one time or another. Ships' forces and MDS narratives indicate that ships' forces are capable of accomplishing this repair without outside assistance, but outside assistance is usually requested to replace the labyrinth seals in order to save ship's force man-hours. MDS narratives involving only labyrinth seal replacements that were reported complete and without outside assistance showed that AOE-1 Class ships reported an average of 70 man-hours to replace the seals of one FDB; AFS-1 and AOR-1 Class ships reported approximately 35 and 28 man-hours, respectively, per FDB for this maintenance action. Assuming that there are no gross manpower or skill-level differences among the FDB technicians of the three ship classes, it appears that the vertically mounted FDBs (AOE-1 Class) require about twice as many man-hours as the horizontally mounted FDBs (AFS-1 and AOR-1 Classes) for labyrinth seal replacements. AOE-1 Class technicians are more likely to let the seals leak longer or ask for outside assistance than technicians of the other classes.

Leaking labyrinth seals are a source of water in the lube oil, as discussed in the previous section. Water in the lube oil causes rust and increased wear of lubricated components.

Labyrinth seals have always been replaced during regular overhauls for the AOE-1 Class ships. Therefore, labyrinth seals have been replaced on 68 occasions on AOE-1 Class ships (56 times during overhauls and 12 times during the intracycles). If it is assumed that half the repairs during overhauls were not necessary, as evidenced by the MDS data preceding those overhauls, labyrinth seal replacements were needed approximately once every 1.2 ship operating years. In order to reduce the ship's force maintenance burden, it would be prudent to have IMAs replace the labyrinth seals of 2 of 8 AOE-1 Class FDBs every 2.5 years. On the basis of available MDS data, it is anticipated that IMAs will expend approximately 65 man-hours to accomplish this task for each FDB with 25 man-hours of assistance from ship's force.

If similar calculations and estimates are made for the AFS-1 and AOR-1 Class ships, IMAs should plan to replace the labyrinth seals of 1 AFS-1 Class FDB every 2 years and 2 AOR-1 Class FDBs every 2.3 years per ship. (AFS-1 Class: 0.54 replacements each SOY, AOR-1 Class: 0.86 replacements every SOY.) IMA man-hour estimates per FDB are 30 man-hours (with 15 ship's force man-hours) for the AFS-1 Class and 25 man-hours (with 10 ship's force man-hours) for the AOR-1 Class. Ship's force will determine which FDB units will receive repairs on the basis of the results of the applicable PMS inspections and operating experience.

General Repairs

There were occasions when ship's force reported multiple repairs to the FDB, consisting of bearing replacements or overhaul, labyrinth packing replacements, lube oil cooler repairs, and other needed repairs. In all these cases work was performed on at least the FDB turbines. In three cases, MDS data indicate that technical representatives or depot personnel overhauled the FDBs. Since depot and technical representative man-hours are not reported, the actual extent of repairs accomplished is unknown. Hence, the repairs that fell into this category could not be used to identify specific repair requirements.

Bearings

AFS-1 reported a total of 804 ship's force man-hours for thrust and journal bearing repairs and replacements during 1973 and 1974. It has reported only 3 equipment maintenance actions of this type since that time, totaling 73 ship's force man-hours. Though the specific corrective action is not known, it is apparent that these bearings are no longer a maintenance or reliability problem.

AOE-4 has reported a total of 486 ship's force man-hours and no IMA man-hours for thrust and journal bearing repairs. Ten equipment maintenance actions averaged 48.6 man-hours each. AOE-3 reported half as many

equipment maintenance actions as AOE-4, each averaging about 15 man-hours. Review of the data and discussions with ships' forces did not identify any specific problems aboard AOE-4 or any maintenance differences aboard AOE-3. This disparity appears to be due to reporting inconsistencies or differences in technician skill levels and practices.

Thrust shoes and bearings, and journal bearings are usually repaired or replaced by ships' forces as they are found to be necessary by quarterly thrust clearance checks required by PMS or as indicated by excessive turbine vibration and noise. Since parts usage data do not indicate excessive bearing usage by any ship class or FDB design, and ships' forces can usually repair bearings in 10 to 25 man-hours (48.6 man-hours for AOE-4) without assistance, scheduled corrective repairs are unwarranted.

Combination Exhaust/Relief Valves

Few combat support ships have reported significant combination exhaust/relief valve failures. In those cases that were reported the combination exhaust/relief valves either began to leak or were stuck -- they would not open at the prescribed pressures. Ships' forces report that they can usually repair these types of failures (see Table 3-6). Ships' forces can do everything except reset and bench test the valves. When valves have to be reset they must be sent to an IMA- or depot-level repair facility. If outside activities must do the resetting, it is most practical to allow those activities also to accomplish the necessary valve repairs. The majority of the combat support ships that reported significant combination exhaust/relief valve failures used outside repair facilities for valve repairs.

The available SARPs show that most ships have the FDB exhaust relief valves overhauled during regular overhauls. MDS narratives prepared before these overhauls did not indicate that these valves always needed repairs.

If it is assumed that half the repairs accomplished during regular overhauls were needed and the intracycle repairs reported were all necessary, the AFS-1 Class ships repaired an average of 1 exhaust/ relief valve every 1.1 SOY, AOE-1 Class ships repaired an average of 2 valves every 1.7 SOY, and AOR-1 Class ships repaired an average of 2 valves every 3.3 SOY. The average reported IMA man-hours per valve repair are calculated to be 18 for the AFS-1 Class, 33 for the AOE-1 Class, and 28 for the AOR-1 Class.

It is recommended that the combat support ships have IMAs repair, reset, and test the FDB combination exhaust/relief valves by the following schedules:

Class	Periodicity	Number of Valves
AFS-1	14 months	1 of 3
AOE-1	20 months	2 of 8
AOR-1	39 months	2 of 6

The specific FDB units to receive these repairs should be determined from the results of the required quarterly ship's force test of the combination exhaust/relief valves. (All applicable FDB MIPs have this requirement.)

3.2.2.2 Conclusions

FDB turbines should be repaired only as needed, because significant failures do not occur frequently. No benefit is gained by overhauling equipment that does not require overhaul. Class C repairs during each ROH should adequately prepare the FDB turbines for intracycle operation. The specific repairs to be accomplished should be identified by performance of appropriate PMS inspections as specified in the applicable FDB MIPs and the ship's CSMP. It is estimated that these repairs will require 70 shipyard man-days per FDB for the AFS-1 90 for the AOE-1 and 70 for the AOR-1 Class ships.

Two maintenance actions reported by a significant number of ships of each ship class can be expected to continue to occur during future operating cycles and either require outside assistance or use outside assistance to reduce the ship's force man-hour burden. Labyrinth seals will need to be replaced, and combination exhaust/relief valves will need repair, testing, and resetting periodically. Consideration should be given to performing these two tasks simultaneously when (1) the assigned periodicities for each task occur within a few months of each other and (2) a single FDB requires both repairs. Performing the two tasks at the same time can reduce the man-hours required for the two tasks because the turbine lagging would have to be removed and replaced only once instead of twice.

3.2.2.3 Recommendations

The recommendations resulting from this review of the FDB turbine maintenance data are as follows:

- Replace labyrinth seals in accordance with the following schedules:

Ship Class	Periodicity	Number of FDBs
AFS-1	24 months	1 of 3
AOE-1	30 months	2 of 8
AOR-1	28 months	2 of 6

IMAs are to perform these tasks with ship's force assistance. The specific FDB units to receive these repairs should be determined by the results of PMS inspections and ship's operating experience.

- Repair, reset, and test the FDB combination exhaust/relief valves in accordance with the following schedules:

Ship Class	Periodicity	Number of FDBs
AFS-1	14 months	1 of 3
AOE-1	20 months	2 of 8
AOR-1	39 months	2 of 6

  The specific FDB units to receive these repairs should be determined by PMS inspection and test results.

- Accomplish Class C repairs to the FDB turbines as found to be necessary by applicable PMS inspections and the ship's CSMP.
- Consider replacing the labyrinth seals and repairing, resetting, and testing the combination exhaust/relief valves simultaneously when the following conditions exist:
  - -- The assigned periodicities for each task occur within a few months of each other
  - -- A single FDB requires both repairs

3.2.3 Valves

3.2.3.1 Discussion

The FDB valves discussed in this section include the steam admission valve, the root steam valve, drain valves and pipes, and control valve assemblies.

Generally, failures of these valves were reported randomly. Typical failure modes included valves leaking through, valves sticking, and valves functioning erratically. The data and ships' forces indicate that these failures can usually be corrected by ships' forces but are often deferred for outside assistance due to the operating schedule or a lack of time to complete the repairs. Since the majority of these failures occurred randomly and were not reported by a significant number of ships of a class, and individual valve failure types usually accounted for less than one maintenance man-hour (ship's force and IMA) per equipment operating year, the majority of the valve failures may best be corrected as needed by ships' forces with assistance from IMAs as required.

One problem was reported by a majority of ships of one class. Six of seven AOR-1 Class ships reported worn steam admission valve stems and bushings on 38 occasions during the data period examined. Ships' forces reported a total of 245 man-hours and IMAs reported 178 man-hours for these maintenance actions. MDS narratives also record that SRF Subic Bay manufactured six steam admission valve stems and reported no maintenance man-hours in MDS. MDS narratives also indicated that 20 equipment maintenance

actions were not reported complete. One ship requested that 15 steam admission valve stems be manufactured, when only 6 FDB steam admission valves are installed on each AOR-1 Class ship. IMAs reported an average of 16 man-hours per valve repair with an average of 6 ship's force assistance man-hours.

These observations and examination of Tables 3-2 and 3-3 indicate that the wear-out of AOR-1 Class steam admission valves is excessive compared with that of the AFS-1 and AOE-1 Class ships.

The available SARPs show that the FDB steam admission valves usually received Class B overhauls during regular overhauls. The MDS data recorded prior to these overhauls do not always indicate that these valves required repairs; therefore, it is assumed that half the overhaul repairs were needed. If these assumed needed repairs are combined with the reported intracycle repairs, the average steam admission valve repair of stems and bushing occurred approximately once every 0.8 ship operating year or every 9.6 months.

Until the exact nature of the AOR-1 Class steam admission valve problem is identified and corrected, the present rate of steam admission valve repairs is expected to continue. Therefore, IMAs and AOR-1 Class personnel may anticipate repairing two FDB steam admission valves approximately every 20 months. The total repairs are expected to require approximately 20 IMA man-hours and 20 ship's force man-hours per valve repair. The valves to be repaired should be identified by ships' forces.

The practice of performing a Class B overhaul on the steam admission valves should be continued on all combat support ships. This task required an average of 8 shipyard man-days per steam admission valve. The remaining FDB valves should be repaired as needed during each shipyard availability. It is estimated that this task will require approximately 5 man-days per shipyard availability.

3.2.3.2 Recommendations

The recommendations resulting from this review of the FDB steam admission valve, root steam valve, drain valves and pipes, and control valve assemblies maintenance data are as follows:

- Repair combat support ship FDB valves as required except for steam admission valves.
- Class B overhaul all combat support ship steam admission valves every regular shipyard availability.
- IMAs, with ship's force assistance, should plan to repair 2 of 6 AOR-1 Class steam admission valves every 20 months. The valves to be repaired will be selected by ships' forces.

Table 3-7. SIGNIFICANT FAILURE MODES: GOVERNOR SUBSYSTEM

Failure Mode	AFS Class				AOE Class				AOR Class			
	Ships Reported (Hull No.)	Equipment Maintenance Actions	Outside Assistance Maintenance Actions*	CASREPs Reported	Ships Reported (Hull No.)	Equipment Maintenance Actions	Outside Assistance Maintenance Actions	CASREPs Reported	Ships Reported (Hull No.)	Equipment Maintenance Actions	Outside Assistance Maintenance Actions*	CASREPs Reported
1. Governor												
a) Inoperative, erratic, sluggish	-5	3	I/3	-	-2,-3,-4	11	-	-	-1,-2,-3, -4,-5,-6	46	D/6,F/16, TR/6	3
b) Drive shaft bent, broken, worn	-	-	-	-	-	-	-	-	-1,-3,-4, -5	8	D/4,I/1	2
c) Other, unknown	-	-	-	1	-	-	-	-	-1,-4	24	D/11,I/10	-
2. Low Lube Oil Trip												
a) Inoperable	-	-	-	-	-2,-3	10	-	1	-1	1	-	2

*D = Depot, I = IMA, TR = Technical Representative, F = Forces Afloat.

3.2.4 Governor Subsystem

3.2.4.1 Discussion

The governor subsystem discussed in this section includes the installed governors and the low lube oil trips installed on the combat support ships. Table 3-7 summarizes the significant failure modes reported in MDS and CASREP data for the FDB governors and low lube oil trip devices.

AFS-1 Class

AFS-1 Class ships have reported very few significant maintenance actions concerning the governor or the low lube oil trip (see Table 3-7). One CASREP was reported during the CASREP data period for failure of a governor servo. The CASREP downtime reported for this failure was 718 hours, all due to maintenance. The average ship's force and IMA man-hours reported per component operating year for the governor and low lube oil trip of each FDB design was one man-hour or less. The governor and low lube oil trip have had very little intracycle maintenance reported against them.

The available AFS-1 Class SARPs show that most governors have received Class B overhauls by shipyards or by one governor manufacturer (Woodward -- AFS-3 through -7). Since governor failures or significant maintenance actions have not occurred within one year after overhaul, and very few have occurred during the remainder of the intracycles examined, it is concluded that these overhauls are contributing to the low intracycle maintenance burden.

MDS data recorded prior to overhauls did not indicate that the governors required overhaul in most cases. Therefore, it is anticipated that these governors could operate longer than the present intracycle periods without a significant increase in intracycle maintenance or failures. The time between overhauls has been almost five years for a few ships and has exceeded five years for one AFS-1 Class ship. It is therefore recommended that the Navy continue to Class B overhaul the AFS-1 Class governors (Woodward governors are to be sent to the manufacturer for overhaul -- AFS-3 through -7) every 60 months. An expenditure of 120 man-hours per equipment should be used for planning purposes (derived from AFS-4 authorized SARP dated 21 December 1979) for AFS-3 through -7. An expenditure of 70 man-hours per equipment should be used for AFS-1 and -2 overhauls (man-hour estimate provided by ARINC Research Corporation, based on DDG-37 Class SARPs).

The practice of overhauling one FDB governor every 20 months will decrease the likelihood of several wear-related failures occurring at once and thus increase the probability that normal ship operations may be conducted at any given time. (The loss of one FDB can be tolerated, as discussed in Section 3.1.) It is recommended that this phased maintenance concept be adopted for AFS-1 Class ships.

The AFS-1 Class SARPs do not specifically list depot-level maintenance for the low lube oil trips, but the lack of maintenance reported against these devices indicates that they present no maintenance problem during operational periods. Therefore, Class C repairs during depot availabilities should suffice for the low lube oil trips. It is estimated that this task will require approximately 10 man-hours per equipment.

AOE-1 Class

AOE-1 Class ships have reported few significant maintenance actions for governor and low lube oil trip repairs. (AOE-3 reported 16 of the 21 significant equipment maintenance actions during a single week.) No IMA man-hours were reported for these equipments and the average ship's force man-hours per component operating year for each FDB design was less than one man-hour (see Tables 3-2 and 3-3). One CASREP was reported for an inoperable low lube oil trip. The total downtime for this CASREP was 73 man-hours, all due to maintenance.

Review of the available AOE-1 Class SARPs indicates that the governors have received Class B overhauls by shipyards during regular overhauls. It is recommended that the Navy continue to overhaul the governors. MDS data recorded prior to overhauls did not usually indicate that governor overhauls were needed. Therefore, the recommended task periodicity is 72 months. This periodicity is selected because some AOE-1 Class ships have operated for almost 60 months with few or no reported governor failures; indications are that a greater overhaul interval could be tolerated. Catastrophic failure of all governors that have operated for 60 months or more is not expected. Failure of as many as four governors can be tolerated -- AOE-1 Class ships each have eight FDBs installed and need only two for all normal operations, as discussed in Section 3.1.

It is also recommended that a phased maintenance concept be adopted in order to further reduce the likelihood of multiple failures due to equipment wear-out and to distribute the ship's force corrective maintenance man-hours that will result from the anticipated equipment failures across the operating cycle. Two governors could be overhauled every 18 months, or four governors could be overhauled every 36 months. In this case, the phased maintenance concept most convenient for the ship should be selected.

It is anticipated that the Class B overhaul of AOE-1 Class FDB governors will require approximately 70 shipyard man-hours per governor. This estimate is based on a review of SARPs of other ship classes carrying similar FDBs.

Available SARPs did not specifically identify the low lube oil trips as Class B overhaul candidates. In view of the low reported low lube oil trip maintenance burden and the apparent ability of ships' forces to correct casualties, Class C repairs should be accomplished as needed. It is estimated that this task will require 10 man-hours per equipment.

AOR-1 Class

The AOR-1 Class ships have reported a significant number of governor failures as shown in Table 3-7. This table also shows that a significant number of these equipment maintenance actions required outside assistance. Almost 70 percent of the reported equipment maintenance actions required IMA, technical representative, or depot assistance. The reported IMA man-hours totaled 723, approximately 24 percent of the total IMA man-hours reported for AOR-1 Class FDBs. Depot man-hours and technical representative man-hours were not reported in MDS. Ship's force man-hours for governor repairs totaled 977 man-hours, approximately 22 percent of the total ship's force man-hours reported for AOR-1 Class FDBs.

Three AOR-1 Class ships reported purchasing four new governors during the MDS data period. Parts costs for AOR-1 Class governors totaled $34,190, approximately 36 percent of the total parts cost reported for the AOR-1 Class FDBs or $112 per component operating year.

These facts would indicate that ships' forces cannot adequately maintain the AOR-1 Class FDB governors without outside assistance. The high percentages of the total FDB man-hours and parts costs for governor repairs indicate (1) these FDB governors are unreliable, or (2) ship's force governor troubleshooting capabilities are inadequate, or (3) some combination of 1 and 2.

Other analyses have shown that Navy personnel at all maintenance levels are sometimes inadequately trained and/or do not have sufficient documentation and test facilities to maintain or repair the Woodward governors. In general, these governors have more parts and are more complicated than the governors made by other manufacturers. Other analyses have also determined that the slightest contamination of the control oil caused parts to stick, resulting in erratic operation or failure of the actuator.

Available AOR-1 Class SARPs show that these governors are routinely returned to the manufacturer for repair and overhaul during regular overhaul periods. This action also suggests that maintenance documentation is inadequate and that the Navy lacks the in-house expertise to repair these governors.

NAVSEACENLANT technical representatives indicate that a school is available that provides instruction on Woodward governor maintenance. This school does not teach governor troubleshooting, but is nonetheless very worthwhile. The school is four weeks long and is taught at Fort Collins, Colorado; length of time required and cost of travel could be the reasons that COs do not send their people to this school. In light of the problems experienced with the AOR-1 Class governors, it is suggested that more commands invest the time and money to send personnel to this school.

The MDS narratives do not indicate the exact nature of the governor failures. The five CASREPs reported for governor failures did not identify a repetitive problem. The FDB significant parts usage summary in Appendix

E does not show a single governor part or group of parts that was used more often than once every 20 component operating years.

It is recommended that consideration be given to conducting a cost analysis to determine which of the following actions would be more cost-effective:

- Incorporate a rotatable pool with manufacturer repair of the governors
- Remove the Woodward governors and install governors that can be maintained and repaired by Navy personnel
- Train Navy personnel at all repair levels to troubleshoot and repair the Woodward governors and improve current documentation (The specific maintenance problems must be identified to determine what training might be required.)

The significant equipment maintenance actions observed occurred more frequently as time since the end of regular overhaul increased. Twelve significant maintenance actions occurred within 2 years of 10 known overhauls or ship commissioning dates. Therefore, an average of 1.2 significant maintenance actions occurred the first 2 years out of overhaul or after commissioning. If all the operational data for AOR-1 through -6 were used, a significant governor maintenance action was reported approximately every 7.2 months or 3.3 significant maintenance actions were required every 2 years. These data also indicate that overhauls, usually Class B, appear to improve governor performance during the first years of the intracycle. Since Navy personnel at all maintenance levels cannot adequately maintain or repair these governors, it is recommended that the Navy continue to return them to the manufacturer for repair.

Some governors have operated without casualty for as long as five years. However, it appears likely that very few of these governors will operate successfully for more than five years between overhauls. For this reason, five years was selected as the maximum overhaul periodicity. It is recommended that three governors per ship be overhauled (rotated) every 30 months; each governor will then be rotated every five years. This action is intended to accomplish the following:

- Allow normal ships' operations at all times with sufficient FDB backup available
- Allow "good" governors to run as long as possible
- Reduce the number of outside assistance corrective maintenance man-hours needed during the intracycle by allowing some governor failures to be left uncorrected until the designated rotation period
- Significantly reduce the probability of all or a significant number of FDB governors being inoperable or erratic at once (This occurrence, all FDBs erratic, inoperable, was reported by three ships on four occasions.)

This task is expected to require approximately 120 man-davs per governor. This man-hour estimate is derived from the AOR-4 authorized SARP, dated 6 September 1980.

Until some other determination is made, it is also recommended that a rotatable pool of governors be developed to accommodate the governor maintenance strategy recommended for AOR-1 through -7 and to avoid unnecessary downtime.

AOR-1 Class low lube oil trips do not appear to present any maintenance problem to ships' forces; therefore, Class C repairs as needed should suffice. It is estimated that this task will require approximately 10 man-hours per equipment.

3.2.4.2 Recommendations

The recommendations resulting from this review of FDB governor maintenance data are as follows:

- Class B overhaul 1 AFS-1 governor every 20 months. (Woodward governors are to be sent to the manufacturer for overhaul -- AFS-3 through -7.)
- Class B overhaul 2 AOE-1 governors every 18 months or 4 AOE-1 governors every 36 months (whichever is more convenient).
- Class B overhaul 3 AOR-1 governors every 30 months. (Woodward governors are to be sent to the manufacturer for overhaul.)
- Consider conducting a cost analysis to determine which of the following actions is more cost-effective (AOR-1 Class):
  - Incorporate a rotatable pool with manufacturer repair of the governors
  - Remove the Woodward governors and install governors that can be maintained and repaired by Navv personnel
  - Train Navy personnel at all repair levels to troubleshoot and repair the Woodward governors and improve current documentation (The specific maintenance problems must be identified to determine what training might be required.)
- In the interim, develop a rotatable pool of governors for AOR-1 through -7 and overhaul (rotate) three governors per AOR-1 Class ship every 30 months.
- Accomplish Class C repairs to AFS-1, AOE-1, and AOR-1 Class low lube oil trips as needed.

3.2.5 Other Repairs, Checks, and Considerations

The preceding sections identified the recurring maintenance tasks that appear to be necessary as a result of review of the maintenance experiences for the FDBs. This section discusses other maintenance considerations identified during the course of this analysis.

3.2.5.1 Component Calibration

FDB lube oil pressure gauges, thermometers, and tachometers are routinely calibrated and repaired by the IMAs as needed. Scheduling of these repairs and calibrations is managed through the Metrology Automated System for Uniform Recall and Reporting (MEASURE) Program. This program is designed to provide participating activities with a standard system for scheduling test, measurement, and diagnostic equipment (TMDE) for recall and calibration at designated facilities, and documenting the data pertaining to calibration and repair actions performed by these facilities. All AFS-1, AOE-1, and AOR-1 Class ships have implemented the MEASURE Program; therefore, these repairs and calibrations need not be scheduled through other maintenance programs.

Ships' forces report that the MEASURE Program is basically sound. Problems arise only when the program is not given adequate attention. The MEASURE Program is generally given a very low priority by fleet personnel due to immediate corrective maintenance problems and reported personnel shortages.

3.2.5.2 PMS Requirements

The applicable FDB MIPs require ships' forces to check, test, and clean various parts of the FDBs once each cycle. These tests should adequately identify most FDB repairs that are needed and should be used as a basis for CSMP work lists.

The applicable FDB MIPs should be changed to reflect the various maintenance cycles planned for AFS-1, AOE-1, and AOR-1 Class ships. All cyclic requirements should be assigned yearly periodicities, since the operating periods between depot availabilities will be of various durations after the phased maintenance or other EOC cycles begin, and that periodicity will avoid unnecessary PMS checks.

Consideration should be given to incorporating turbine and blower vibration analysis into the PMS schedule to identify needed repairs and impending failures that might not be identified through visual or operational tests. Vibration analysis can also be used as an additional tool to select which FDB most needs repair.

AOR-1 and AOE-1 Class FDB MIPs require ships' forces to measure the fan blade clearance each quarter. This check is intended to determine whether the rotor is out of position and to prevent possible fan blade contact with the blower casing. Past analyses performed on turbine-driven FDBs for the DDG-37 Class and CG-16 and -26 Classes have determined that this requirement is unnecessary because the journal bearings would have to be totally wiped for the rotor to be far enough out of position for the fan blades to hit the casing. The MDS and CASREP data identified no casualties of that type. During the data period, approximately 15 percent of the population of journal bearings were reported replaced. Fan blade clearance has not been a problem and is not expected to become one. Therefore, this step (Step 2) of the following MRC cards should be changed to

"R" (as required), which would be called for by excessive or noticeably increased vibration:

MIP	Periodicity	MRC Control Number
F-002/78-72	Q-5	72-B26T-Q
F-002/115-40	Q-3	72-B64X-N
F-002/126-29	Q-4	94-E71T-N
F-002/136-85	Q-6	85-H64S-N

3.2.5.3 FDB Operations

Ships' forces report that the combat support ships operate one or more FDBs approximately 60 to 85 percent of the time during the intracycle. During under-way periods and throughout deployments, some FDBs are operating.

Sometimes this operating pace means that technicians are not able promptly to perform needed preventive or corrective maintenance on the FDBs. Increased operation during deployments, then, necessitates increased corrective maintenance due to a normal expected increase in wear-related casualties. During these times, technicians actually have less control over when and how much maintenance is performed due to watchstanding, the ship's operational pace, and the main propulsion status (which boilers are on the line). This problem becomes even more acute when a ship has only three boilers instead of four, as is the situation with AFS-1 and AOR-1 Class ships, and when a ship has only one FDB installed per boiler, as AFS-1 Class ships do. AFS-1 Class ships are most likely to have this type of problem and AOE-1 Class ships are the least likely.

Ships' forces have suggested installing a motor-driven blower with sufficient capacity to steam an associated boiler during auxiliary steaming. It is recommended that consideration be given to that suggestion for the following potential benefits:

- Technicians would have the needed flexibility to perform required corrective and preventive maintenance during in-port periods, thus allowing a level-loading of maintenance rather than being forced to defer maintenance or overload work centers during cold iron or slack periods.
- Motor-driven FDBs would provide operational backups for the light-off blowers.
- The severity of the experienced FDB failures may be reduced or in some cases significant failures may be eliminated by allowing technicians to correct minor problems as needed.

The consideration is particularly applicable to AFS-1 Class ships.

3.2.5.4 Valve Maintenance

Ships' forces report that most valves can be repaired as needed at the organizational level. However, testing and resetting of valves, when necessary, must be done by IMAs or depot-level facilities because test benches are not installed on combat support ships.

It is recommended that consideration be given to installing a valve test bench aboard combat support ships for the following potential benefits:

- Ship-to-shop man-hours now expended could be used to repair and test the valves.
- Valves could be repaired promptly, eliminating the "tear out all the valves now because an IMA is available" practice and allowing a more constant valve maintenance schedule.
- IMA man-hours would be reduced, allowing the affected IMA work centers to tend to more urgent repairs and provide other ships with better turnaround.
- A great deal of paperwork for ships' forces and IMAs would be eliminated.

3.2.5.5 Other Considerations

Discussions with NAVSSES personnel indicate that ship's force personnel with limited IMA and depot-level assistance are able to repair the FDBs and keep them operational. Equipment repairs are accomplished as needed, and overhauls are accomplished during shipyard availabilities. Often, the FDBs are repaired or overhauled, but they are not returned to the original manufacturers' design specifications. The result is that the FDBs, though operational, experience some intermittent failures, because repair parts no longer fit exactly as they should, equipment alignment is not as designed, or tolerances have been changed.

To preclude these types of equipment problems, NAVSSES practical experience indicates that some FDBs should be returned to the manufacturers for overhaul during regular shipyard availabilities. The data examined during this analysis does not support or refute this practice. There were no manufacturer overhauls of the FDBs reported in the SARPs examined. Therefore, the practice of returning the FDBs to the manufacturers for overhaul cannot be recommended. However, this type of problem could be very real. It is suggested that a study be initiated to determine whether manufacturer overhauls are warranted for the combat support ships.

3.2.5.6 Recommendations

The recommendations listed below resulted from the review of maintenance experience for the combat support ship FDB and discussions with

technical and operational personnel. The specific recommendations are as follows:

- Assign yearly periodicities to replace the cyclic requirements currently specified in applicable FDB MIPs.
- Consider incorporating turbine and blower vibration analysis into the PMS schedule.
- Change Step 2 of the following MRC cards to "R" (as required):

MIP	Periodicity	MRC Control Number
F-002/78-72	Q-5	72-B26T-Q
F-002/115-40	Q-3	72-B64X-N
F-002/126-29	Q-4	94-E71T-N
F-002/136-85	Q-6	85-H64S-N

- Consider installing a motor-driven blower with sufficient capacity to steam an associated boiler during auxiliary steaming. (This consideration is particularly applicable to AFS-1 Class ships.)
- Consider installing a valve test bench aboard combat support ships.
- Initiate a study to determine whether manufacturer overhauls of FDBs are warranted for the combat support ships.

3.3 MAINTENANCE STRATEGY

3.3.1 Intracycle Maintenance

The data indicate that ships' forces, with limited IMA assistance, have traditionally been able to effect the needed FDB repairs during the intracycles and that this maintenance strategy should continue. FDB maintenance histories indicate that some equipment failures can be anticipated, and IMA man-hours should be reserved for these failures as discussed in Section 3.2.

A significant portion of the FDB corrective maintenance man-hours is a function of how well ship's force keeps the lube oil subsystem clean and is not solely due to equipment wear-out. Thus, it is not possible to estimate when particular system failures will occur. This review of the significant FDB failures indicated that most failures occurred randomly.

3.3.2 Overhaul Planning

Results of this analysis indicate that the entire FDB system need not be overhauled to prepare for each operating cycle. The FDB governors and throttle valves were the only equipments identified that will require depot-level overhaul before each operating cycle.

Design differences of the FDB governors and redundancy differences of the installed equipment were the two most significant factors affecting the FDB need for depot-level repairs. Some governor designs require significant repairs more often than other governor designs, as discussed in Section 3.2.4. However, different FDB redundancies across the three ship classes examined allow some ship classes to tolerate more FDB losses without degradation of basic mission capabilities than other ship classes, as discussed in Section 3.1. Thus there are variations in the recommended periodicities for FDB governor overhauls for different classes. The other FDB components and subsystems require only Class C repairs to prepare for the intracycle. It is therefore prudent to accomplish all necessary Class C repairs to the other FDB components at the same time that the governors are being overhauled. The components of each FDB unit will then be overhauled or repaired at the depot level every five to six years.

Five years was determined to be the maximum "safe" interval between AFS-1 and AOR-1 Class FDB governor overhauls, because some ships of these classes have operated successfully during this time. The AOR-1 Class FDB governor maintenance histories indicate that these governors are failing more often as time-since-overhaul increases, and ships' forces cannot adequately maintain these governors. Therefore, five years is the maximum repair interval suggested for AOR-1 Class FDB governors. Failures will occur late within this interval, but the phased overhauls recommended are expected to prevent failures in quantities significant enough to affect normal operations.

Six years was determined to be the maximum "safe" interval between AOE-1 Class FDB governor overhauls, because sufficient redundancy exists for boilers (four) and FDBs (two per boiler) to allow some failures to occur without affecting normal ship operations. Again, phased overhauls will reduce the likelihood of concurrent total failures of all FDBs.

<u>Five years for the AFS-1 Class ships and six years for the AOE-1 Class ships should not be construed to be the maximum repair interval</u>. It is anticipated that these intervals could be extended, but a maximum interval could not be determined because no ships have operated longer.

A greater risk would be taken in extending these intervals for the AFS-1 Class ships due to their lack of equipment redundancy (three boilers, three FDBs). The addition of a motor-driven blower, as suggested in Section 3.2.5.3, would significantly reduce this risk.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The following conclusions resulted from this analysis:

- FDB governors and steam admission valves for the AFS-1, AOE-1, and AOR-1 Classes are the only equipments identified in this analysis that clearly benefitted from depot-level overhauls. Class B overhauls of the other FDB equipments did not improve equipment reliability or availability; therefore, such action is not recommended. These equipments can be repaired, as needed, by ships' forces and IMAs.
- A significant amount of corrective maintenance is a function of how clean ships' forces keep the lube oil subsystem. As a result, many of the significant failures identified, associated with contaminated lube oil, occurred randomly throughout the data period examined.
- The FDB lube oil system modifications, to be installed as shipalts to the AFS-1, AOE-1, and AOR-1 Class ships, are expected to reduce the corrective maintenance burden and improve FDB reliability and maintainability when installed.
- Ships' forces, with limited IMA assistance, are capable of accomplishing most repairs to the combat support ship FDBs, with the following exceptions:
  - -- The Woodward governors installed aboard AOR-1 through -6. These cannot be properly maintained or repaired by ship's force, IMAs, or shipyards.
  - -- Catastrophic failures. These are usually caused by operating accidents and are not the result of equipment wear-out.
- AOR-1 Class ships have experienced a FDB governor failure rate significantly higher than that of the AFS-1 or AOE-1 Classes. Therefore, extension of the governor overhaul interval beyond five years is not considered prudent.

- AOE-1 Class FDB governors may be "safely" overhauled once every six years due to a phased maintenance repair strategy, a relatively low failure rate, and sufficient equipment redundancy (four boilers, eight FDBs). Six years, however, should not be construed to be the maximum possible governor repair interval. It is anticipated that the interval could be extended beyond six years, but a maximum interval could not be determined because no AOE-1 Class ships have operated longer than five years.

- AFS-1 Class FDB governors need to be overhauled only once every five years. More frequent overhauls are unnecessary due to a phased maintenance repair strategy and a relatively low failure rate. Five years, however, should not be construed to be the maximum possible governor repair interval. It is anticipated that the interval could be extended beyond five years, but this action would be taken with significant risk due to the lack of equipment redundancy aboard AFS-1 Class ships (three boilers, three FDBs).

4.2 RECOMMENDATIONS

Recommendations for scheduled corrective and restorative maintenance actions that are to be accomplished by depots or IMAs are summarized in Table 4-1.

Improvements to the forced draft blower equipments are categorized as follows:

- Design Improvements
  -- Recommended shipalts, ordalts, and field changes
  -- Recommended equipment redesign or replacement
- Maintenance Strategy Improvements
  -- PMS changes
  -- Policy
- Support Improvements
  -- ILS improvements
  -- Maintenance-capability improvements
- Other

These recommended improvements are summarized in Table 4-2.

Table 4-1. RECOMMENDED IMA AND DEPOT CORRECTIVE AND RESTORATIVE MAINTENANCE ACTIONS

Task Identification			Component or Subsystem	Level of Repair	Task Description	Applicable Ships	Quantity Installed per Ship	Repair Estimate [Man-Hours (M-H) or Man-Days (M-D)]	Task Frequency	Section Reference
Task Type	SWAB	Number								
Q	251-1X	1	Turbines	Depot	Accomplish Class C repairs *to the FDB turbines* as determined to be necessary by applicable FDB MIPs and ship's CSMP.	AFS-1 Class	3	70 M-D per turbine	60 months	3.2.2, 3.3.2
						AOE-1 Class	8	90 M-D per turbine	72 months	
						AOR-1 Class	6	70 M-D per turbine	60 months	
Q	251-1X	2	Turbines	IMA/SF	Replace labyrinth seals (see Table 4-2, Recommendation Numbers 11 and 13).	AFS-1 Class	3	30/15 M-H per turbine	72 months	3.2.2.[illegible]
						AOE-1 Class	8	65/25 M-H per turbine	120 months	
						AOR-1 Class	6	25/10 M-H per turbine	84 months	
Q	251-1X	3	Turbines	IMA	Repair, reset, and test the combination exhaust/relief valves (see Table 4-2, Recommendation Numbers 12 and 13).	AFS-1 Class	3	18 M-H per valve	42 months	3.2.2.1
						AOE-1 Class	8	33 M-H per valve	60 months	
						AOR-1 Class	6	28 M-H per valve	117 months	
E	251-1X	1	*Governors*	Depot	Class B overhaul governors (see Table 4-2, Recommendation Numbers 16, 17, and 18).	AFS-1, AFS-2	3	70 M-H per governor	60 months	3.2.4.1
						AFS-3, -4, -5, -6, -7	3	120 M-H per governor	60 months	
						AOE-1 Class	8	70 M-H per governor	72 months	
						AOR-1 Class	6	120 M-D per governor	60 months	
Q	251-1X	4	Low Lube Oil Trips	Depot	Accomplish Class C repairs.	All Combat Support Ships	AFS-1 - 3 AOR-1 - 6 AOE-1 - 8	10 M-H per equipment	ROH	3.2.4.1
Q	251-1X	5	Lube Oil Subsystem Coolers	IMA	Chemically clean, hydrostatically test, and repair the lube oil coolers (see Table 4-2, Recommendation Number 10). Note: These tasks should be reevaluated after the accomplishment of the applicable FDB lube oil system modification shipalts.	AFS-1 Class	3	30 M-H per cooler	30 months	3.2.1
						AOE-1 Class	8	30 M-H per cooler	48 months	
						AOR-1 Class	6	30 M-H per cooler	72 months	

(continued)

Table 4-1. (continued)

Task Identification			Component or Subsystem	Level of Repair	Task Description	Applicable Ships	Quantity Installed per Ship	Repair Estimate [Man-Hours (M-H) or Man-Days (M-D)]	Task Frequency	Section Reference
Task Type	SWAB	Number								
E	251-1X	2	Steam Admission Valves	Depot	Class B overhaul steam admission valves	All Combat Support Ships	AFS-1 - 3 AOR-1 - 6 AOE-1 - 8	8 M-D per valve	ROH	3.2.3.1
Q	251-1X	6	Steam Admission Valves	IMA/SF	Repair steam admission valves (see Table 4-2, Recommendation Number 15).	AOR-1 Class	6	20/20 M-H per valve	60 months	3.2.3.1
Q	251-1X	7	FDB Valves	Depot	Repair FDB valves as needed. This task includes FDB root steam valves, drain valves and pipes, and control valve assemblies.	All Combat Support Ships	*	5 M-D per task	ROH	3.2.3.1

*Exact quantities for each ship could not be determined.

Table 4-2. RECOMMENDED IMPROVEMENTS

Component	Number	Recommendation	Section Reference
Design Improvements — Recommended Shipalts, Ordalts, and Field Changes			
Lube Oil Subsystem	1	Accomplish the FDB lube oil modification on the following shipalts at the earliest opportunity: • AFS-1-393K • AOE-1-446K • AOR-1-421K	3.2.1
Design Improvements — Recommended Equipment Redesign or Replacement			
FDB Unit	2	Consider installing a motor-driven blower with sufficient capacity to steam an associated boiler under auxiliary load (This consideration is particularly applicable to AFS-1 Class ships.)	3.2.5
Gland Exhaust System	3	Examine the need for upgraded gland exhaust systems on the combat support ships and take appropriate action if upgrading is determined to be necessary.	3.2.1
Maintenance Strategy Improvements — PMS Changes			
Lube Oil Subsystem	4	Make the following additions or changes to incorporate a weekly requirement to clean and inspect oil filters for the listed MIPs: • F002/037-28 - change Q-3 and R-5Q to W-( ) and R-( )W, respectively • F-002/067-76 - add W( ) requirements • F-002/085-87 - add W( ) requirement • F-002/115-40 - change R-7Q to R-( )W • F-002/126-29 - change R-3Q to R-( )W Note: These tasks should be reevaluated after the accomplishment of the applicable FDB lube oil system modification shipalts.	3.2.1
Lube Oil Subsystem Coolers	5	Make the following changes to the listed MIPs (Task - chemically clean, hydrostatically test, and repair FDB lube oil coolers): • F-002/037-28 - change C-6 to 24M-( ) (4 of 8 installed) • F-002/067-76 - change C-6 to 30M-( ) (3 of 3 installed) • F-002/078-72 - change C-6 to 24M-( ) (4 of 8 installed) • F-002/085-87 - change C-6 to 30M-( ) (3 of 3 installed) • F-002/115-40 - change 60M-4 to 36M-( ) (3 of 6 installed) • F-002/126-29 - change C-5 to 24M( ) (4 of 8 installed) • F-002/136-85 - change C-4 to 36M( ) (3 of 6 installed) Note: These tasks should be reevaluated after the accomplishment of the applicable FDB lube oil system modification shipalts.	3.2.1
All	6	Assign periodicities (in years) to all cyclic [C-( )] requirements of the applicable FDB MIPs.	3.2.1, 3.2.5
Lube Oil Pump	7	Develop and add to the following MIPs a requirement to inspect and measure lube oil pump drive gear assembly backlash each ROH: F-002/037-28, F-002/067-76, F-002/085-87, F-002/115-40, and F-002/136-85	3.2.1
Blower	8	Change Step 2 of the following MRC cards to "R" (as required): MIP — Periodicity — MRC Control Number F-002/78-72 — Q-5 — 72-B26T-Q F-002/115-40 — Q-3 — 72-B64X-N F-002/126-29 — Q-4 — 94-E71T-N F-002/136-85 — Q-6 — 85-H64S-N	3.2.5

(continued)

Table 4-2. (continued)

Component	Number	Recommendation	Section Reference
		Maintenance Strategy Improvements — Policy	
Lube Oil Subsystem	9	Repair as determined to be necessary by PMS MIPs and ship's CSMP.	3.2.1
Lube Oil Subsystem Coolers	10	Chemically clean, hydrostatically test, and repair the lube oil coolers with the following frequencies: • AFS-1 Class - 2.5 years (3 of 3 installed) • AOE-1 Class - 2 years (4 of 8 installed) • AOR-1 Class - 3 years (3 of 6 installed)	3.2.1
Turbine	11	Replace labyrinth seals with the following frequencies: • AFS-1 Class - 24 months (1 of 3) • AOE-1 Class - 30 months (2 of 8) • AOR-1 Class - 28 months (2 of 6)	3.2.2
	12	Repair, reset, and test the combination exhaust/relief valves with the following frequencies: • AFS-1 Class - 14 months (1 of 3) • AOE-1 Class - 20 months (2 of 8) • AOR-1 Class - 39 months (2 of 6)	3.2.2
	13	Consider replacing the labyrinth seals and repairing, resetting, and testing the combination exhaust/relief valves simultaneously when the following conditions exist: • The assigned periodicities for each task occur within a few months of each other. • A single FDB can be identified that requires both repairs.	3.2.2
Valves	14	Repair FDB valves as required, except for steam admission valves.	3.2.3.1
	15	Repair 2 of 6 AOR-1 Class steam admission valves every 20 months.	3.2.3.1
Governors	16	Class B overhaul 1 AFS-1 Class governor every 20 months. (Woodward governors are to be sent to manufacturer for overhaul.)	3.2.4.1
	17	Class B overhaul 2 AOE-1 Class governors every 18 months or 4 every 36 months (whichever is more convenient).	3.2.4.1
	18	Class B overhaul (rotate) 3 AOR-1 Class governors every 30 months. (Woodward governors are to be sent to manufacturer for overhaul.)	3.2.4.1
Turbine/Blower	19	Consider incorporating turbine and blower vibration analysis into the PMS schedule.	3.2.5
FDBs	20	The FDB Units should be repaired as necessary, with phased overhauls of the governors and steam admission valves every 5 or 6 years, depending on the ship class.	3.3.2
		Support Improvements — ILS Improvements	
Governors	21	Consider conducting a cost analysis to determine which of the following actions is most cost-effective (AOR-1 Class): • Incorporate a rotatable pool with manufacturer repair of the governors. • Remove the Woodward governors and install governors that can be maintained and repaired by Navy personnel. • Train Navy personnel at all repair levels to troubleshoot and repair the Woodward governors and improve current documentation. (A determination of the specific maintenance problems is necessary to establish what training might be required.)	3.2.4.1
	22	In the interim, develop a rotatable pool of governors for AOR-1 through -7.	3.2.4.1

(continued)

Table 4-2. (continued)

Component	Number	Recommendation	Section Reference
Support Improvements — Maintenance Capability Improvements			
Lube Oil Sumps	23	Identify those areas of the AOE-3 and -4 lube oil sump which cannot be reached for cleaning and initiate appropriate action to correct this problem.	3.2.1
Valves	24	Consider installing a valve test bench aboard combat support ships.	3.2.5
Other			
FDB Units	25	Initiate a study to determine whether manufacturer's overhauls are warranted for the combat support ships.	3.2.5.5

APPENDIX A

SYSTEM BOUNDARIES FOR FORCED DRAFT BLOWERS

Appendix A is a portion of the FDB Repair Inspection Requirements (RIR) excerpted from a copy of Fleet Machinery Notes, Volume 15, Number 1, dated May 1980. It defines the boundaries of the FDB system and was used as the primary reference source in establishing the system boundaries for this analysis.

The boundary of this RIR includes:

Forced Draft Blowers and Driving Units

- Steam: From the first flange of the main steam inlet to the first flange of the exhaust flange of the associated exhaust/relief valve.
- Air End: From air inlet to discharge elbow flange.

Associated Equipment

- Auxiliary Lube Oil Pump Motor*
- Coolers*
- Exhaust/Relief Valves*
- Filters*
- Foundations
- Gauges
- Governors*
- Instrumentation
- Lube Oil Strainers
- Lube Oil Sumps*
- Pumps*
- Steam Admission Valves*
- Tachometers
- Thermometers
- Turbines*

*These major components of the FDB units were subjected to analysis and are discussed in this report.

APPENDIX B

FORCED DRAFT BLOWER INSTALLATION CONFIGURATION FOR AFS-1, AOE-1, AND AOR-1 CLASS SHIPS

The forced draft blowers discussed in this report are composed principally of the components listed in Table B-1. The table provides detailed information regarding the individual component nomenclature, APL number, hull applicability, and number of components installed on each hull. There are instances where it appears from the table that particular key components are not installed on some of the ships. In those cases, one of the following conditions exist:

- The component has no separate APL.
- The component is not listed in the applicable type commander's COSAL and no data were reported in MDS or CASREP data for that component.

Table B-1. COMPONENTS OF THE FORCED DRAFT BLOWER SYSTEM

Nomenclature	APL/CID	Quantity by Hull Number																	
		AFS							AOR							AOE			
		1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4
Fan STM TDVN 41000CFM	057800180																	8	8
Fan STM TDVN 28400CFM	057960012															8			
Fan STM TDVN 32000CFM	057960013	3	3																
Fan STM TDVN 34400CFM	057960020			3	3	3	3	3											
Fan STM TDVN 22000CFM	057960034														6				
Fan STM TDVN 4100CFM	057990011																8		
Fan STM TDVN 22000CFM	057990018								6	6	6	6	6	6					
Pump OSCG HND 5GPM 22PSI	016170053	3	3	3	3	3	3	3											
Pump RCIPG HND 1.15GPM 150PSI	016170125																8		
Pump RTY HND 14GPM 25PSI	016200230																	8	8
Pump RTY PWR 22GPM 100PSI	)17210085																8		
Pump RTY PWR 14GPM 35PSI	017210097								6	6	6	6	6	6					
Pump RTY PWR	017210098							3							6				
Pump RTY PWR 22GPM 90PSI	017210101																	8	8
Pump RTY PWR 3GPM	017010002	3	3																
Gage Press DL IND	452010079														3				
Filter FD PRESS MDL	480020143																8		
Filter FD PRESS MDL	480020164								6	6	6	6	6	6					
Filter FD PRESS MDL	480020181																	8	8
Filter FD PRESS MDL	480020216														6				
Filter FD PRESS MDL	480060220			3	3	3	3	3											
Filter FD PRESS MDL	480060245															8			
Operator Valve	610360025				3	3													

(continued)

Table B-1. (continued)

Nomenclature	APL/CID	Quantity by Hull Number																	
		AFS							AOR							AOE			
		1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4
Operator Valve	610360047						3												
Control RLY SENDER 3-15PSI	612010179											6							
Control POSTN 3-15PSI	612100053															8			
Control Vol CMBR	612020298Z			12															
Control Diaphragm Motor	612020359																8		
Control RLY	612020396			3															
Control POSTN 3-15PSI	612120408																8		
Control POSTN	612020431																	8	8
Cooler FD 11.9 SQFT	030130448	3	3																
Cooler FD 11.9 SQFT	030130574															8			
Cooler FD 6.7 SQFT	030130711								6	6	6	6	6	6					
Cooler FL 13.3 SQFT	030130765			3	3	3	3	3											
Cooler FL	030250012																	8	8
Cooler FL 1.5 SQFT	032010048			3			3												
Cooler FD 11 SQFT	030130604																8		
Bearing ASSY THR PV 5 x 5	370030001																8		
Bearing ASSY THR PV 6 x 6	370010302																	8	8
Bearing ASSY THR PV 4 x 4	370030035								6	6	6	6	6	6					
Bearing ASSY THR PV 5 x 5	370030038			3	3	3	3	3							6				
Bearing ASSY THR PV 4.375 x 4.375	370030016	3	3													8			
Governor HYD TURB REGG	701110253								6	6	6	6	6	6					
Governor HYD TURB REGG	701110278			3	3	3	3	3											
Governor HYD TURB REGG	701110279														6				

(continued)

Table B-1. (continued)																				
Nomenclature	APL/CID	Quantity by Hull Number																		
		AFS							AOR							AOE				
		1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4
Strainer Y 3IN STL	750170347								6	6	6	6	6	6					
Strainer Y .25IN L	750170448															[illegible]			
Strainer Y 2IN STL	750170451																	[illegible]	[illegible]
Motor AC 230/115V .25HP	174620221	3																	
Motor AC 115/230V .33HP	175504723		3																
Valve ANL .5IPS 600PSI STL	882000408											3							
Valve ANL 1.5IPS 1500PSI STL	882001270															[illegible]	[illegible]		
Valve ANL 2IPS 600PSI	882003100																	8	8
Valve Check .75IPS 600PSI STL	882031130			3	3	3	3	3											
Valve Gate 1IPS 150PSI BRZ	882040914			3	3	3	3	3											
Valve Gage 1.25IPS 200PSI BRZ	88204359						4												
Valve Gate 2IPS 800PSI STL	882044673						1												
Valve Gate 1.25IPS 800PSI STL	882044657							3											
Valve Globe .5IPS 2000PSI STL	882051469																	8	
Valve Globe .5IPS 600PSI STL	*82051765				12														
Valve Globe 1.25IPS 200PSI BRZ	882054125						3												
Valve Globe .5IPS 800PSI STL	882054370															6	4	7	
Valve Globe .25IPS 600PSI STL	882055566																		10
Valve Globe .75IPS 600PSI STL	882056034																		8
Valve Globe 2IPS 800PSI STL	882054548								6	6	6	6	6	6					
Valve PG NONLUB 1.25IPS 150PSI	882081071																	8	8
Valve	882080872								6	6			6	6					
Valve RED .25IPS 100PSI ALUM	882095362										6								

(continued)

Table B-1. (continued)																			
Nomenclature	APL/CID	Quantity by Hull Number																	
		AFS							AOR							AOE			
		1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4
Valve RED .5IPS 2000PSI-150PSI	882090491	3	3																
Valve DPHRM CONT 2IPS 600PSI	882190638															8			
Valve DPHRM CONT 2IPS 600PSI	882191272																	8	8
Valve DPHRM CONT 2IPS 600PSI	882190758	3	3																
Valve RED SPCL .25IPS 200-95PSI	882240565															8			
Valve RED x RELF .25IPS 60PSI	882240747									6		6							
Valve ANL SPCL 1IPS 100PSI	882241151								6	6	6	6	6	6					
Valve EXH x RELF 8IPS 150PSI	882241179																8		
Valve EXH x RELF 4IPS 150PSI	882241200								6	6	6	6	6	6	6				
Valve EXH x RELF 8IPS 150PSI	882241421																	8	8
Valve RED x RELF .25IPS 40PSI	882240736	3	3																
Valve BTFL 16IPS 150PSI	882290624		1	3	3	3		3											
Valve BTFL	882290625		2																
Valve BRFL 16IPS STL	882291405						3												

APPENDIX C

MAJOR FDB DIFFERENCES BY SHIP CLASS

Table C-1 lists the major differences among forced draft blowers within each class and across the three ship classes examined. These specific differences were not addressed in the text of this report unless gross maintenance history differences were found to be the result of these design differences.

Table C-1. FDB DESIGN DIFFERENCES BY SHIP CLASS			
Characteristics and Manufacturers	Differences in Characteristics by Ship Class		
	AFS-1 Class: 1 FDB per Boiler (3 Boilers)	AOE-1 Class: 2 FDBs per Boiler (4 Boilers)	AOR-1 Class: 2 FDBs per Boiler (3 Boilers)
Main FDB APLs			
Hardie-Tynes	057960013 057960020	057960012	057960034
Elliot		057990011	057990018
Westinghouse		057800180	
Rated Blower Capacity (cfm)			
Hardie-Tynes	32,000 34,400	28,400	22,000
Elliot		40,600	22,000
Westinghouse		41,000	
Turbine Speed (rpm)			
Hardie-Tynes	4,825 5,420	4,450	5,400
Elliot		7,950	7,900
Westinghouse		8,000	
Turbine Operating Steam Temperature (°F)			
Hardie-Tynes	545 545	600	640
Elliot		840	640
Westinghouse		840	
Turbine Stages			
Hardie-Tynes	1 1	1	1
Elliot		1	1
Westinghouse		2	
Shaft Mounting			
Hardie-Tynes	Horizontal Horizontal	Vertical	Horizontal
Elliot		Vertical	Horizontal
Westinghouse		Vertical	

APPENDIX D

SUMMARY OF CASREP INFORMATION FOR THE FORCED DRAFT BLOWER

The 42 CASREPs reported by the AFS-1, AOR-1, and AOR-1 Class ships were grouped into one of the three general categories of blower/turbines, lube oil system, or governor/low lube oil trip, and into the appropriate subgroups within each group on the basis of the initial cause reported for each CASREP. This information is presented in Table D-1. The table also shows the total number of CASREPs reported against each different FDB design for each initial cause, together with the total number of CASREP downtime man-hours due to supply and maintenance.

A summary of the parts ordered under the reported CASREPs is presented in Table D-2. Each part reported is identified by Navy stock number or other identifier, part nomenclature, and the associated APL number. The total number of parts ordered by the ships of each FDB design is also shown with the quantity of each part allowed per hull, as listed on the appropriate APL; the total number of CASREPs requiring each part; and the total number of hulls requiring each part.

Table D-1. FDB CASREP SUMMARY

Reason for CASREP	Number of CASREPs							CASREP Downtime (Man-Hours)		
	AFS-1, AFS-2	AFS-3, AFS-7	AOE-1	AOE-2	AOE-3, AOE-4	AOR-1, AOR-6	AOR-7	Due to Supply	Due to Maintenance	Total
1. Blower/Turbine										
A. Shaft out of alignment						1		0	1,928	1,928
B. Turbine casing ruptured			1					0	1,346	1,346
C. Seals or packing leak				3	1			0	975	975
D. Thrust bearing wiped		1						0	5,576	5,576
E. Thrust shoes wiped					1			0	310	310
F. Turbine blades weak or damaged					8			0	23,800	23,800
G. Journal bearings wiped					1			2,256	1,814	4,070
H. Tachometer failed	1			2				2,851	903	3,754
I. Rotor damaged (personnel error)					1			83	695	778
J. Unknown					4			308	2,027	2,335
Subtotal	1	1	1	5	16	1	0	5,498	39,374	44,872
2. Lube Oil System										
A. Oil supply lines clogged				1		1		240	705	945
B. L.O. pump shaft sheared or damaged						1		0	121	121
C. L.O. pump failed					1	2		0	1,691	1,691
D. L.O. pump drive gear retainer failed					1			1,200	148	1,348
E. Unknown					1			0	236	236
Subtotal	0	0	0	1	3	4	0	1,440	2,901	4,341
3. Governor/Low Lube Oil Trip										
A. Push rod piston bent						1		0	20	20
B. Gears, pistons, shafts worn						1		68	5	73
C. Governor erratic, sluggish, inoperative						3		116	399	515
D. Low L.O. trip inoperative						2		0	857	857
E. Governor servo failed		1						0	718	718
Subtotal	0	1	0	1	0	7	0	184	1,999	2,183
Totals	1	2	1	7	19	12	0	7,122	44,274	51,396

Table D-2. CASREP PARTS SUMMARY

Part NSN	Part Nomenclature	APL Number	Quantity Required							Quantity Allowed per Hull	Number of CASREPs Requiring Part	Number of Hulls Requiring Part
			AFS-1, AFS-2	AFS-3, AFS-7	AOE-1	AOE-2	AOE-3, AOE-4	AOR-1, AOR-[illegible]	AOR-7			
1H-2825-00-317-4410	Seal-Oil THR BRG	057960013	1							1	1	1
9Z-9535-00-288-5985	Unknown	Unknown	1							Unknown	1	1
1H-2825-00-950-1912	Collar-THR			1						0	1	1
575-264	Unknown	Unknown		1						Unknown	1	1
1H-2825-00-228-1988	Ring-Seal	370030001				2				0	1	1
1H-2825-00-059-6740	Packing Assy-LBYR	057800180					8			2	4	1
1H-2825-00-059-6742	Packing Assy-LBYR	057800180					8			2	4	1
1H-2825-00-059-6737	Bearing-PV JRNL	057800180					4			2	2	1
2H-2825-00-059-6805	Rotor Assy-TURB COMP	057800180					2			0	2	1
1H-2825-00-862-5678	Ring-THR BRG Assy SE	057800180					2			1	1	1
9G-4140-00-860-7978	Seal, Oil	057800180					3			1	3	1
9G-4140-00-860-7979	Seal, Oil	057800180					3			1	3	1
9Z-3120-00-805-6365	Washer-THR	370010302					2			0	1	1
460-182396	Unknown	Unknown					1			Unknown	1	1
1H-2825-00-059-6798	Blading Set-TURB	057800180					1			0	1	1
1H-2825-00-059-6804	Blading Set-TURB	057800180					1			0	1	1
2H-2825-01-036-2008	Governor, STM TURB	701110253						4		0	3	1
1H-2825-00-908-2373	Shoe, THR BRG	370030035						16		8	2	2
9C-3020-00-903-2773	Gear-WM	057990018						1		1	1	1
9C-3020-00-913-5955	Gear-HLCL	057990018						1		2	1	1
9C-3040-00-366-3216	Gear-DR GOV	701110253						2		0	1	1
9Z-3120-00-908-2377	Bearing SLV-UPR x LWR	057990018						2		2	1	1
9Z-5330-01-053-9725	Packing Assy							3		2	1	1
3RCK-X962	Unknown	Unknown						2		Unknown	2	1

APPENDIX E

SIGNIFICANT PARTS USAGE

Table E-1 presents a summary of the significant parts usage reported by the AFS-1, AOE-1, and AOR-1 Class ships. Significant parts were those that were ordered on at least one CASREP or were used more than once per ten component operating years.

Each significant part is identified by national stock number and nomenclature. Table E-1 shows the quantity of each part ordered by each unique FDB design and the quantity of each part allowed, as specified by the associated APL. The table also shows the total number of different hulls receiving each part, the total number of associated JCNs for each part, and the average number of component operating years between purchases of each part.

The data indicate that the present supply support is adequate.

Table E-1. SIGNIFICANT PARTS USAGE SUMMARY

Part National Stock Number	Part Nomenclature	Quantity Purchased							Quantity Allowed per Hull	Number of Hulls Purchasing Part	Number of JCNs	Average Time Between Purchases* (Component Operating Years)
		AFS-1, AFS-2	AFS-3, AFS-7	AOE-1	AOE-2	AOE-3, AOE-4	AOR-1, AOR-6	AOR-7				
1H-2010-00-036-3082	Shoe, Thrust Bearing	8		16					8	2	3	3.3/4.3
**1H-2825-00-950-1921	Pad, Thrust Bearing		12						6	2	2	10.9
1H-2825-00-620-7409	Shoe Assy-THR BRG				12				12	1	1	5.7
1H-2010-00-446-7572	Shoe, Thrust Bearing					74			12	2	5	1.8
**1H-2825-00-908-2373	Shoe, THR BRG						105		8	6	11	2.6
**9Z-3120-00-908-2377	BRG SLV-UPR x LWR						29		2	6	10	9.6
**2H-2825-00-036-2008	Governor, STM TURB						7		0	4	5	39.7
**9C-3040-00-366-3216	Gear-DR GOV						13		0	5	6	21.4
**1H-2825-00-913-5955	Gear-HLCL						9		1	5	7	30.9
**9Z-5330-01-053-9725	Packing Assembly						7		2	1	2	39.7
**9C-3020-00-903-2773	Gear-WM						3		1	2	3	92.6
**1H-2825-00-317-4410	Seal-Oil THR BRG	1							1	1	1	26.4
**1H-2825-00-228-1988	Ring-Seal				2				0	1	1	34
**1H-2825-00-059-6740	Packing Assy-LBYR					11			2	2	5	11.8
**1H-2825-00-059-6742	Packing Assy-LBYR					12			2	2	6	10.9
**kG0272509 095805636	Beaning-PV JRNL					16			2	2	10	8.15
**2H-2825-00-059-6805	Rotor Assy-TURB COMP					--			0	0	0	---
**1H-2825-00-862-5678	Ring-THR BRG ASSY-SE					3			1	2	3	43.5
**9G-4140-00-860-7978	Seal, Oil					3			1	1	3	43.5
**9G-4140-00-860-7979	Seal, Oil					4			1	1	4	32.6
**9Z-3120-00-805-6365	Washer-THR					1			0	1	1	130.4
**1H-2825-00-059-6798	Blading Set-TURB					3			0	1	1	43.5
**1H-2825-00-059-6804	Blading Set-TURB					3			0	1	1	43.5

*Average time between purchases = design ship operating years × number of FDBs per hull ÷ number of parts replaced.
**Parts associated with at least one CASREP.

APPENDIX F

SHIPALT STATUS FOR FORCED DRAFT BLOWERS

Table F-1 shows the status of current approved shipalts for the AFS-1, AOE-1, and AOR-1 Class forced draft blower systems. The source for the completion codes listed on the table is the type commander status of shipalt management information system (SAMIS) as of 10 June 1981.

Table F-1. SHIPALT STATUS

Shipalt, AER Number	Brief Description	Status by Hull		
		AFS	AOE	AOR
		1 2 3 4 5 6 7	1 2 3 4	1 2 3 4 5 6 7
AFS-393K	FDB Lube Oil System Mods	A B A A B B A	- - - -	- - - - - - -
AOE-344D		- - - - - - -	N N B C	- - - - - - -
AOR-421K		- - - - - - -	- - - -	A B A B A B A
AOE-446K		- - - - - - -	A A A B	- - - - - - -
AFS-416D	FDB L.O. Temperature Regulating Valve	A A A A A A A	- - - -	- - - - - - -
AOR-469D		- - - - - - -	- - - -	A B A B A B
AOR-259D	FDB Governor Oil Cooler Mod	- - - - - - -	- - - -	C B C B C B C
AER-AOE-39	Mod to AOE Forced Draft Blowers	- - - - - - -	N N C C	- - - - - - -

A = Applicable, not authorized for accomplishment.

B = Applicable, authorized for accomplishment.

C = Complete.

N = Not applicable.

APPENDIX G

SOURCES OF INFORMATION

The specific sources of information used in this analysis are as follows:

1. Generation IV MDS narrative and part data for the AFS-1, AOE-1, and AOR-1 Classes for the period 1 January 1971 through 30 June 1980.

2. CASREPs for the same ships for the period 1 January 1977 through 30 June 1980.

3. Naval Sea Support Center Pacific, Planned Maintenance System Automated List of Effective Pages (PMS-5), Qtr 3-80, report date 19 July 1980.

4. NSTM Chapter 9450, Lubricating Oils, Greases and Hydraulic Fluids, and Lubrication Systems, 15 June 1977.

5. NAVSHIPS 353-0181, Main Forced Draft Blowers (AFS-1, -2), October 1962.

6. NAVSHIPS 353-0172, Main Forced Draft Blowers (AOE-1), December 1964.

7. NAVSHIPS 0953-000-3000, Main Forced Draft Blowers (AOE-2), January 1978.

8. NAVSEA S9251-AF-MMA-010-FDB, Forced Draft Blower, Turbine Driven, AOE-3 and AOE-4, November 1979.

9. NAVSHIPS 0953-001-3010, Main Forced Draft Blower (AOR-1, -2, -3, -4, -5, and -6), April 1967.

10. NAVSHIPS 0953-019-9010, Main Forced Draft Blowers (AOR-7), 11 July 1974.

11. System Maintenance Analysis Reports, as follows:

    - FF-1052 Class Combustion Air System, ARINC Research Publication 1646-03-1-1566, December 1976.

- <u>DDG-37 Class Combustion Air System</u>, ARINC Research Publication 1652-03-13-1739, April 1978.
- <u>CG-16 and CG-26 Class 1200 PSI Propulsion Plant, SWAB Group 200</u>, ARINC Research Publication 1671-04-3-2119, November 1979.

12. Ship Alteration and Repair Packages (SARPs):

    - AFS-1 dated 11 April 1977
    - AFS-2 dated 8 May 1980
    - AFS-3 dated 20 December 1978
    - AFS-4 dated 21 December 1979
    - AFS-5 dated 12 July 1978
    - AFS-6 dated 12 July 1978
    - AFS-7 dated 15 November 1979
    - AOE-1 dated 5 October 1979
    - AOE-2 dated 22 September 1976
    - AOE-3 dated 26 December 1978
    - AOE-4 dated 1976
    - AOR-1 dated 16 November 1978
    - AOR-2 undated
    - AOR-3 dated 15 June 1979
    - AOR-4 dated 26 September 1980
    - AOR-5 dated 5 January 1977
    - AOR-6 dated April 1978

    No SARP was provided for AOR-7.

13. Reports of ARINC Research Corporation visits to AOE-4 (USS DETROIT), 11 May 1981, and COMNAVSURFLANT Code N4111, NAVSEACENLANT DET Code 750, and AFS-6 (USS SAN DIEGO), 20-22 May 1981.

14. Steam Propulsion Plant Improvement Program Shipalt documentation: Table I.b - Shipalt Listing by Ship Type/Class, January 1981; Table III - Ship Summary Status, 4 April 1981.

15. COMNAVSURFLANT and COMNAVSURFPAC Type Commanders' Coordinated Shipboard Allowance Lists (COSALs), dated 24 April 1979 and 25 June 1979, respectively.

16. Shipalt briefs and SAMIS shipalt information for AFS-1, AOE-1, and AOR-1 Class forced draft blowers.

17. Maintenance index pages (MIPs) and maintenance requirement cards (MRCs) for the AFS-1, AOE-1, and AOR-1 Class forced draft blowers.

18. Allowance parts lists (APLs) for selected components of the AFS-1, AOE-1, and AOR-1 Class forced draft blowers.

19. OPNAVINST 4790.4, Material Maintenance Management (3-M) Manual, Volumes I, II, and III, June 1973.

20. Common Configuration Class List for AOE-1, AFS-1, AD-14, AO-177, AOR-1, and AE-26 Classes, 11 August 1980.

DATE
ILME